Local Knowledge of Coffee Productivity, Biodiversity and Ecosystem Services in Coffee Plantations in El Hato Watershed, Guatemala

A GUIDE TO USING THE CAFNET-GUATEMALA KNOWLEDGE BASE

Plate 1. Interviewing on a coffee farm in El Hato Watershed. Photograph taken by Rudy del Cid, August 2008.

C. Cerdán[1-2]; G. Lamond[1]; E. Martin[1]; T. Pagella[1]; G. Soto[2]; F.L. Sinclair[1]

[1] School of Environment and Natural Resources, Bangor University, Gwynedd, Wales, UK LL57 2UW
[2] Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica

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This guide uses an approach that was pioneered in Ghana (Moss *et al*, 2001) to introduce first time users of AKT5 to existing knowledge bases and it was subsequently used in Thailand (Pagella *et al*, 2002) and Lesotho (Waliszewski *et al*, 2003). The template for this document was used by kind permission of the authors of these previous documents. The software itself has been developed over many years primarily by Knowledge Engineer James Doores in collaboration with Edinburgh University in Scotland (UK).

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1. Local knowledge of coffee productivity, biodiversity and ecosystem services in coffee plantations in El Hato Watershed, Guatemala

A GUIDE TO USING THE CAFNET-GUATEMALA KNOWLEDGE BASE

1.1 What is the purpose of this guide?

This publication is intended to guide users through a knowledge base (Kb) created in **El Hato Watershed** of **San Agustín Acasaguastlán Municipality, El Progreso Department, Guatemala**. It has been designed to assist new users in exploring the local knowledge base that has been developed for the CAFNET project in El Hato Watershed, Guatemala. The knowledge base has been developed by a number of researchers and contains agro-ecological knowledge primarily about coffee productivity, species diversity and water provisioning services within coffee plantations in El Hato Watershed.

Greater explanation regarding the AKT5 methodology and the steps to creating a knowledge base can be found in the comprehensive user manual written by Dixon *et al* (2001). The principles of knowledge base creation have been explained by Sinclair and Walker (1998) and Walker and Sinclair (1998); how this approach applies within a natural resource management context is discussed by Sinclair and Walker (1999) and Sinclair and Joshi (2000). The software and manual can be downloaded from the AKT5 website at **http://akt.bangor.ac.uk.**

1.2 Consulting knowledge bases

Local knowledge can help researchers and development workers explain the rationale behind farmers' actions and can contribute towards more effective decision making in developing appropriate strategies for particular development issues. Knowledge bases can be consulted by:

- viewing sets of *statements* that fall under specific *topics*,
- using search facilities within AKT to find out the details of particular *terms* (words),
- generating *diagrams* from *statements* and using these to investigate causal relationships, and
- using customised *tools* (small computer programs that are incorporated into AKT5 that interrogate and reason with the knowledge base)

1.3 The Agro-ecological Knowledge Toolkit (AKT5)

1.3.1 What is AKT5?

AKT5 is a methodology and software that enables the user to create a *knowledge base* about a chosen *domain* which is shaped by the topic of the knowledge base, the research area and the people chosen to be interviewed. In this case **people who manage and work in coffee plantations** were interviewed in order to collect '**local knowledge of coffee productivity, biodiversity and ecosystem services in coffee plantations**' in **El Hato Watershed**. A knowledge base is built up by collating knowledge about a chosen topic from a variety of sources (usually farmers, scientists, extension workers and scientific literature).

So far, AKT5 has been used primarily as an analytical research tool to explore the extent and nature of agro-ecological knowledge at a wide range of localities. This has led to profound changes in the way that research and extension are planned in areas of Africa (Kenya, Tanzania, Ghana and Cameroon), Asia (Nepal, Thailand, Sri Lanka and Indonesia) and Latin America (Colombia, Costa Rica and Nicaragua), as well as forming the basis for successful participatory crop improvement and the development of decision support tools for the production of extension materials tailored to farmer circumstances. When local knowledge is explicitly stored within a knowledge base, it can then be consulted by natural resource scientists, policy makers and development workers in a variety of ways to help them meet their own objectives.

1.3.2 What is knowledge?

To define *knowledge* is to enter a philosophical minefield; nevertheless an explicit definition is required in this context. For the purposes of AKT5, *knowledge* is the outcome of the interpretation of data, whereas, *data* is recorded observations that may be either qualitative or quantitative. *Knowledge* in this context could be called *interpreted observations* that are often shared within and across farming communities. *Knowledge* is distinct from *understanding*, which is a result of the interpretation of knowledge or data and is specific to the interpreter. These definitions are more fully discussed in Sinclair and Walker (1999).

1.3.3 What is a knowledge base?

A *knowledge base* is a store of knowledge that consists of a collection of *statements* and locally defined taxonomic relationships, created using AKT5 software. Each *statement* is tagged (referenced) with its source of knowledge (this could be a singular person, a number of people if it came from a group interview or a literature reference).

The knowledge is organised according to a number of principles:

- *topics* arrange knowledge around specific subject areas, e.g. '**flowering of tree and plant species**'. *Topic hierarchies* gather similar topics under an umbrella title e.g. '**pollination of tree and plant species**'**,** '**flowering of tree and plant species**' and '**fruiting of tree and plant species**' all fall under the broader topic of '**phenology of tree and plant species**' (Figure 1), and

- *object hierarchies* organise knowledge about specific *objects* under umbrella terms, e.g. '**american sweetgum**', '**avocado trees**' (with its own subobjects of 'avocado' and 'coyo_avocado') and '**caulote**' are all types of tree that have been identified by farmers as having a 'dense crown' and would, therefore, fall under the umbrella term '**dense crown trees**', as they share this attribute (Figure 2).

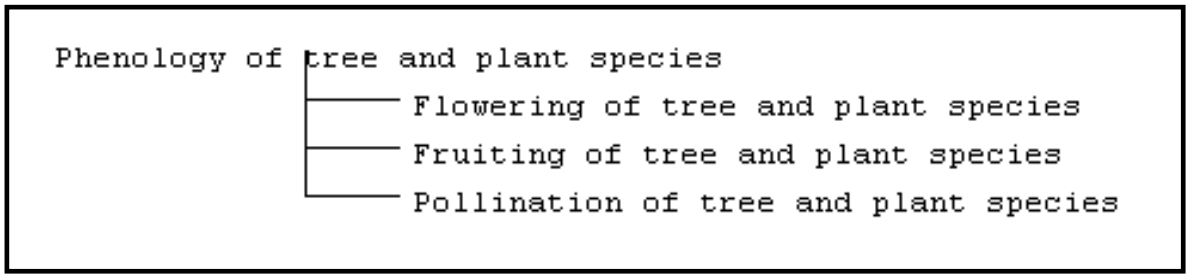
Phenology of tree and plant species
Flowering of tree and plant species
Fruiting of tree and plant species
Pollination of tree and plant species

Figure 1. The topic 'phenology of tree and plant species' is arranged in a topic hierarchy tree with a list of subtopics.

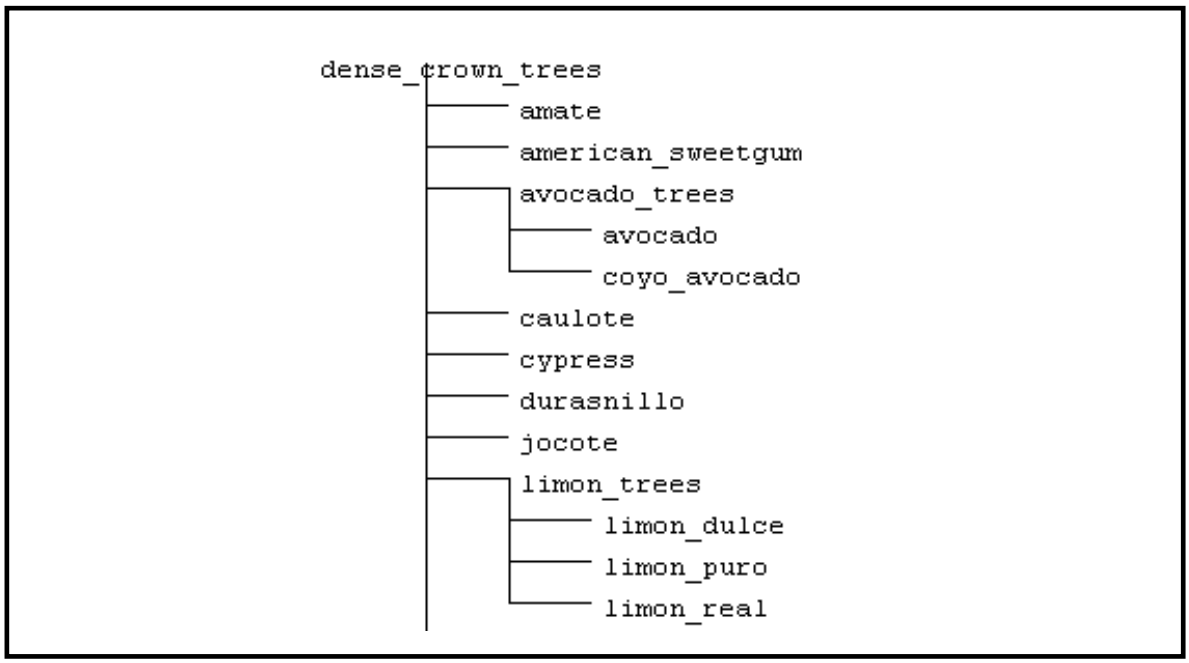

Figure 2. The object 'dense crown trees' is arranged in an object hierarchy tree with a list of its subobjects (what is shown is just a small sample of the available dense crown trees).

2. The CAFNET - Guatemala knowledge base: Context of the study

2.1 CAFNET

CAFNET is a four-year European Commission funded project that hopes to make some positive changes to how the coffee process chain operates in order to improve coffee farmer income while at the same time protecting 'biodiversity hotspots'. A major concern of the project is ecosystem services[2] and how coffee farming practices can benefit the environment as well as the farmer. Approximately 125 million people across Asia, Africa and Latin America depend on coffee for their livelihoods and it is the second most valuable export commodity after petroleum (Lashermes and Anthony, 2007; Osorio, 2002). The importance of coffee both as a cash crop and as a possible 'buffer' crop around protected areas has been highlighted by the CAFNET project and the local knowledge research that has so far been carried out aims to lead to a better understanding of farming practices carried out by the coffee farmers, who are an integral part of the system.

Ecosystem service provision can be considered an important indicator of sustainable land use practices and, for example, whereas most of the research on biodiversity in coffee systems has concentrated on documenting tree species richness and abundance by surveys and data collection (Méndez et al, 2006), the objective of this work was to document the knowledge held by those involved directly with coffee production. This was in order to understand locally held perceptions of both floral and faunal diversity and agro-ecological interactions within coffee systems. For the local knowledge component of the CAFNET project the main objectives were:

1. to document local agro-ecological knowledge of coffee farmers on the diversity of species found within coffee plantations and the interactions between species in terms of productivity and sustainability, and

2. to identify any key gaps in the knowledge held by coffee farmers or scientists and to pull out any contrasting or comparative knowledge between coffee farmers and scientists.

2.2 Study area

Central America is the central geographic region of America, which connects northern South America (Colombia) with southern North America (Chiapas, Tabasco, Campeche and Quintana Roo Mexican states). Central America is made up by seven countries: Belize, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama.

The Central American region has approximately 522,000 square kilometres with coffee being grown on an estimated 893,000 hectares of this area (CEPAL, 2002). Coffee has been one of the main agricultural crops and source of export earnings over the last century and currently plays an important role in the national income of many countries; 7.2% of the GDP (Gross Domestic Product) of Nicaragua, 4.2% of Guatemala GDP and 1.3% of Costa Rica GDP (ICAFE, 2005).

Three areas were selected in Central America to take part in the CAFNET project and they were located in Guatemala, Nicaragua and Costa Rica. Selection criteria for the

[2] As elaborated on in the Millenium Ecosystem Assessment, 2005.

research areas were according to their geo-hydrological attributes, the percentage of land covered by coffee plantations and their proximity to protected areas and wildlife parks; this was to assess their potential as buffer zones for purposes of enhancing biodiversity conservation and watershed protection in fragmented landscapes. In Guatemala, the CAFNET researchers were working in El Hato Watershed of San Agustín Acasaguastlán Municipality, El Progreso Department, Guatemala.

The El Hato Watershed is one of many watersheds that feed into the River Montagua and it covers a percentage of the land area of the Sierra de Las Minas Biosphere Reserve. This reserve is the second largest protected area in Guatemala and is noted for its high species diversity, with 2000 species having been recorded, including endemic species, which number at least 70 (IARNA et al., 2006). The range in altitude from 250 to 2,600 m asl from the River Montagua at the bottom of the valley to the Sierra de Las Minas also means there is a great number of micro environments with associated species (Ellis and Taylor 2007).

The proximity of this particular watershed to Sierra de Las Minas, the range of climatic zones present in the area, and the lack of coffee producer organisation (for both conventional and organic farmers) within the El Hato Watershed were factors contributing to its selection. Coffee in this area was mainly planted under the shade of *Inga* spp., a leguminous native tree species. Additionally, some other native and exotic trees would often form part of the shade canopy in order for the farmers to obtain fruits, timber or firewood. In some parts of the watershed, cardamom (*Eletaria cardamomum*) was also intercropped with coffee.

Plate 2. Coffee under *Inga* spp. trees in El Carmen community within El Hato Watershed. Photograph taken by Carlos Cerdán, August 2008.

2.3 Methodology

2.3.1 Location and definition of knowledge bases

This guide is primarily focused on examining coffee farmers' explanatory knowledge of the role that coffee faming plays within its surrounding ecosystem; relationships between species found on coffee plantations, farming practices, and the wider environment (e.g. impacts on soil, water, coffee productivity) were considered important.

Interviews were conducted across eight communities in El Hato Watershed, with the altitude ranging from just below 1000m to 1700m above sea level (asl). The communities visited were largely located at the higher altitudes within the coffee zone of the watershed, however, two communities, El Cimiento and El Terraplen were notably lower (just below 1000m to approximately 1,200 m asl) and experienced hotter and drier conditions as a result.

2.3.2 Informant selection

Informants were selected according to size of farm, altitudinal range, and whether they were employing organic or conventional farming methods. By stratifying coffee farmers according to these criteria, there was more scope for comparing and contrasting their knowledge to see where the cross-strata knowledge and/or differences might lie.

The farms included in the study were classified as small (less than 1 manzana[3] to 5 manzanas), medium (between 5 and 10 manzanas), and large (above 10 manzanas). Distinction could be made between different sized coffee farms due to differences in the composition and diversity of tree species planted with coffee; small producers were likely to retain more shade trees within coffee plantations to supplement their income and for subsistence purposes.

While most of the coffee farms were located in communities at a high altitudinal range in the watershed, coffee was also being produced on plantations that experienced a warmer and drier climate due to altitude and/or micro-climatic conditions. Informants were selected accordingly, in order to obtain local agro-ecological knowledge from farmers who were producing coffee under various climatic conditions. Differences in composition of tree species and management of coffee were deemed likely.

While the majority of the coffee farms in the watershed were conventional, i.e. made use of chemical fertilisers, there were also some organic coffee farms. The absence of chemical inputs and consequent possible differences in management made stratification along these lines seem reasonable.

2.3.3 Compilation of the knowledge base

Interviews with key informants were held on coffee plantations where possible and lasted no more than an hour, unless the informant was keen to continue. The interviews were informal and semi-structured, using non-leading questions in order to elicit informants' knowledge, rather than influence answers.

[3] 1 manzana is equal to 0.69 hectares.

Notes were taken and digital recording devices were used where permission was granted; this then enabled the researchers to go through the interviews thoroughly afterwards and break them down into unitary statements to enter into the AKT5 knowledge bases. This led to a process of iterative evaluation throughout knowledge base creation, with repeat interviews taking place where necessary to clarify or add value to what had already been said by informants. Many of the interviews were conducted in El Hato Watershed during July-August 2007 and then followed up in August 2008.

Creating a knowledge base enables the local context of the knowledge to be attached to the sources and the statements that are entered from interviews with those sources; this is done by a 'memo' function. Source details that are required in AKT5 are the name of the informant, location of the interview, and gender. In the Guatemalan case, other information included size of coffee farm, occupation, age, and climatic zone of the area. Further context was recorded in source and statement memos.

2.4 The knowledge base

The cafnet_guatemala Kb was built up from interviews with one female and twenty-eight male informants. The age of informants was categorised into 'below 35' (young), '35-60' (middle) and 'above 60' (old); the dominant age range was '35-60' with seventeen interviews, followed by 'above 60' with nine interviews and 'below 35' with three interviews. Tables 1 and 2 (below) summarise the information gathered from different locations and different sized farms. As can be noted, the majority of interviews took place in 'High' communities and with small farmers who had between 0-5 manzanas dedicated to coffee.

There are a total of 654 statements in the Kb with 576 of these demonstrating causal relationships. A high number of causal statements would indicate a fairly high level of explanatory knowledge that was able to be articulated by the coffee farmers. Out of the 654 statements there are 136 conditions attached to statements; this means that there are particular conditions that need to be in place for the statement to be applicable and these should be considered carefully when analysing the knowledge base.

Location	**Climatic zone according to management practices**	**No. of informants**	**No. of associated statements**
El Carmen	**High**	**6**	**203**
La Hierbabuena	**High**	**7**	**226**
Las Parcelas	**High**	**6**	**156**
Las Delicias	**Medium/high**	**1**	**3**
Los Balsamos	**Medium/high**	**1**	**70**

El Terraplen	**Medium**	**2**	**48**
Los Albores	**Low**	**3**	**143**
El Cimiento	**Low**	**3**	**91**

Table 1. Location and climatic zones of the sources from cafnet_guatemala Kb.

Table 2. Size of coffee farms and associated statements from cafnet_guatemala Kb.

Size of coffee farm (cafetal)	**No. of informants**	**No. of associated statements**
0-5 manzanas	**20**	**441**
Above 5 – 10 manzanas	**6**	**253**
Above 10 manzanas	**3**	**110**

Within the Kb there are number of object hierarchies and topic hierarchies that have been created to enable the user to search chunks of knowledge much quicker than would otherwise be possible. How to do this will be explored in the following section.

There are 38 object hierarchies that classify tree and animal species according to the agro-ecological interactions that farmers attributed to them (e.g., 'animals that damage coffee'). The object hierarchies show the importance of particular attributes of trees for them to be maintained in a farming landscape, with possible short and long term trade-offs evident (for instance, there might be a tree that attracts many animal species but has a negative impact on coffee productivity).

There are 40 topics arranged into five topic hierarchies that organise the farmers' knowledge under useful headings that can be searched easily by the user. The five topic hierarchies are entitled 'Commonly held knowledge' (broken down into sections according to farm size and climatic zone), 'Habitat provision' (for mammals, birds and insects), 'Phenology of tree and plant species' (times of flowering, fruiting and pollination), 'Trees and biodiversity' (interactions between trees and animal species), and 'Trees and water infiltration' (complex tree, soil and water interactions).

Plate 3. Observations on a coffee farm. Photograph taken by Rudy de Cid, August 2008.

3. How to consult the knowledge base

3.1 Using the guide:

It is suggested that the user start with '**A quick sightseeing tour around AKT5**' to familiarise themselves with the different functions of the AKT5 software. Once this is completed the user should then be able to consult the knowledge base according to particular topics of interest using any of the examples provided:

- **Valuing tree attributes in terms of biodiversity conservation**
- **Desirable attributes of trees within coffee plantations**
- **Comparison of knowledge held by coffee farmers in different climatic zones**
- **Role of coffee plantations in water provisioning services**

The topics given above indicate the type of knowledge contained in the knowledge bases and the ways in which to access it will be explored below. After completing '**A quick sightseeing tour around AKT5**' the user will be able to consult the knowledge base using topics, different search options and exploring diagrams. These skills will then be reinforced and developed by the section entitled '**Exploring the knowledge base; some highlights from local knowledge**' which introduces more contextual information and how to utilise AKT5 tools.

Once the user has completed these sections they should then be able to explore the knowledge base independently. There are tools designed to help the user pull out relevant information and some of the more useful ones are listed in '**Appendix 1: Tools for analysing the knowledge**'. Definitions of key terms and concepts used in the sightseeing tour and the AKT5 software are included in '**Appendix 2: Glossary**'.

The user should note that not all functions of the software are explained in this publication because the software is used for both creating and accessing knowledge bases. The '**User Manual**' (Dixon et al., 2001) provides a more comprehensive guide to the software and how to create your own knowledge base.

3.2 A quick sightseeing tour around AKT5

This quick tour around AKT5 with the **cafnet_guatemala** knowledge base is designed to help familiarise you with the AKT5 software and the ways in which you can manipulate a knowledge base.

Getting Started:

1. Install and then load the **AKT5** program onto your computer by clicking on the appropriate icon from the **Start** menu.

2. Always start AKT5 and then load a knowledge base, never start by clicking on Kb file to open.

3. Open the **cafnet_guatemala** by selecting '**KB'** from the tool bar at the top of the page, clicking on '**Open Kb**'**…**then selecting the **cafnet_guatemala** from its saved location and clicking on '**Open**'.

Welcome Dialog Box

Read the '**Welcome Memo**' dialog box to get an idea of what the knowledge base is about. Select '**Further Details**' to find out where, when and how the knowledge base was made. Click on '**Pictures/Diagrams**', read the text at the top and then view each picture by clicking on it. When you have finished with each picture/diagram, click on the **X** in the top right corner to close the dialog box. The diagrams provide background information about the livelihoods of the farmers who participated in the research. Click on the **X** in the top right corner to return to the 'Welcome Memo' screen.

Switching the language of the knowledge base (English-Spanish, Spanish-English)

In some knowledge bases, including this one, it is possible to switch from English script to a largely Spanish script[4]. To access this function go to the '**Tool**' drop down menu on the main toolbar in the top left hand corner of the page. Select '**transpose_formal_terms_and_synonyms (Kb, Position)**' from the '**General**' drop down menu which can be found under '**System Tools**' (Figure 3).

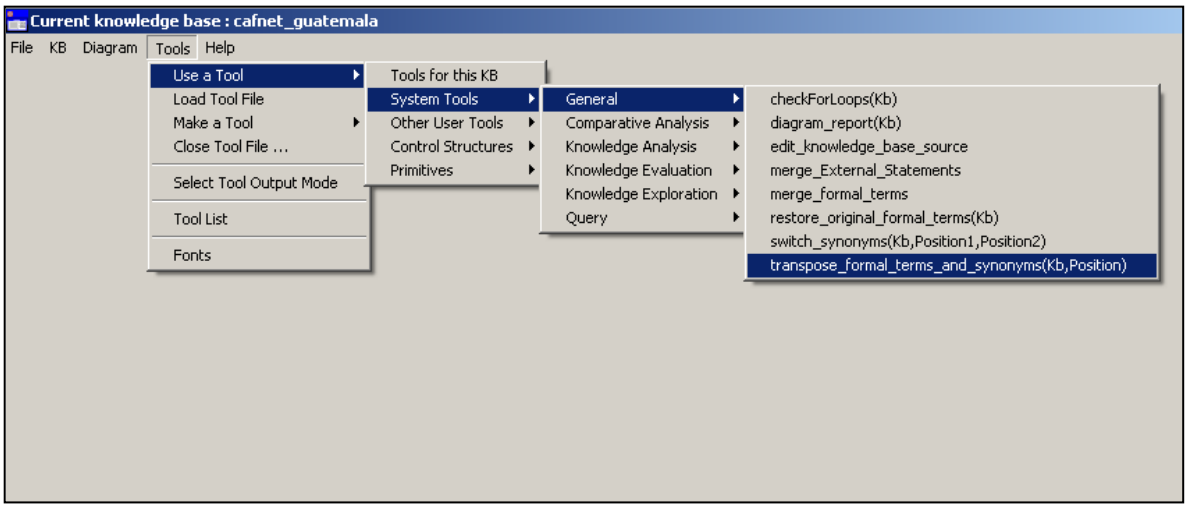

Figure 3. 'Tools' menu.

A new dialog box will appear, click on '**Run**' (select '**Description**' to see an explanation of the tool). Another dialog box is produced; the name of the knowledge base will appear in the '**KB**' field and the '**Position**' field will be blank. Type in '**1**' in the '**Position**' field (this will change the current formal terms to their first position synonyms). Once you have done this, select '**Continue**' and wait for the tool to run (for large knowledge bases this can take a few minutes). Where there is no synonym available in position 1, the term will keep its original name in the main Kb language.

When the tool has finished running, a '**Tool output**' is produced which tells you it has successfully carried out transposing the terms. Click on **Close** to close the window, and then click on **X** to close the list of tools and return to the main AKT5 screen. *(To return to the original format i.e. the English script, you would need to use the tool*

[4] This is achieved by utilisation of the synonym function of the AKT5 program. This allows substitution of all the main language formal terms for a listed synonym. Switching formal term/synonym positions requires the use of an AKT5 system tool.

*'**restore_original_terms(Kb)**' which is found in the same list of tools as '**transpose_formal_terms_and_synonyms (Kb, Position)**').*

When viewing the statements and diagrams after converting the knowledge base into Spanish script, you will see that some words remain in English. These are reserved words that have restricted meaning within the AKT5 system. Topics, topic hierarchies and sources cannot be switched using this tool and will remain in the main Kb language. It is only formal terms and statements which can be viewed in the Spanish translation. Computers with modern versions of the Windows operating system will also be able to show the diagrams in Spanish.

Now, let's look at Topics by selecting '**Topic Hierarchies**' from the '**KB**' drop down menu on the toolbar on the main AKT5 screen *or* from the '**Welcome Memo**' dialog box.

Topic hierarchies

Topics are ways of organising information around a particular subject e.g. 'Coffee and soil' or 'Habitat for birds'. In ***Topic hierarchies*** specific knowledge can be grouped together as topics and arranged under more general headings, e.g. 'Coffee and soil', 'Coffee and water' and 'Water and soil' all fall under the general topic hierarchy of 'Trees and water infiltration'.

On the left you can see a list of the topic hierarchies in the knowledge base. Highlight **'Commonly held knowledge**'. On the right you will see a dialog box with a column called '**Topics in hierarchy**' containing a list of all the topics in this topic hierarchy. Next to this column you will see '**Commonly held knowledge**' highlighted in the '**Topic**' box and immediately below all the '**Immed. Subtopics**'.

Select '**View Tree**' and scroll down the page; this will show you the full topic hierarchy with *all* its 'subtopics'. Click on **Close** to go back to the previous window.

Now select '**Common knowledge of organic farmers**' from the '**Topics in hierarchy**' list. You will see that it now appears in the 'Topic' box with '**Commonly held knowledge**' specified as the 'Supertopic' above it and '**High organic farmers**' specified as one of the 'Immed. Subtopics' below it.

Close this dialog box to return to the '**Topic Hierarchies**' box. Now highlight in turn each topic hierarchy listed under 'Topic Hierarchies'. Answer the following question:

Question: What topics are shown to be in the topic hierarchy 'Phenology of tree and plant species?

Click on **Close** on both dialog boxes to return to the 'Welcome Memo' and **Close** again to arrive at the main AKT5 screen.

Sources

Sources tell you the origin of a statement. All statements have a source, which can be of 2 types: an interview with a person (e.g. a farmer) or a literature reference (e.g. a

journal article). In the case of the Guatemalan knowledge base, all the sources are people directly working with coffee.

Go to the tool bar on the main AKT5 screen (top left) and select '**Sources**' from the '**KB**' drop down menu.

On the left is a list of all the sources interviewed for the knowledge base. Let us look at one of them. Highlight the name '**Alberto Albizures 2008a**' and click on '**Details'**. A dialog box appears giving you the name of the person interviewed, the interviewer(s) and date of interview. You are also given the gender, occupation, age, and a location which is their community of residence. Furthermore, the coffee plantation size of the interviewee and the climatic zone of the area are listed. If you select '**Memo**', you will be given any further details that the creator of the knowledge base deemed important contextual information.

Click on **X** on all three dialog boxes to return to the main AKT5 screen.

Topics

From the tool bar on the main AKT5 screen select '**Topics**' from the '**KB**' drop down menu.

This gives you a list of all the topics in the knowledge base. Highlight '**coffee and water**' and select '**Details/Edit**'. In the dialog box that appears you will see in the 'Boolean Search String' how the topic was created – it is a search for any of the following object terms –'coffee_plants', 'water', 'rainy_season' and 'rainfall'.

Click on '**Show use in statements'** at the bottom of the dialog box and a list of all the statements on 'coffee and water' will appear. There are 9 statements in all. As you scroll through the list of statements you will notice that the translation does not sound like a natural use of English - this is illustrated and explained further on. **Close** the list of statements and the 'topic details' dialog box.

Try the same thing with the topic '**Habitat for birds**'. Answer the following question:

Question: How many statements are attached to the topic 'Habitat for birds'?

You can see that the number of statements generated by a topic is often a large number to look through. We will now continue to look at smaller collections of knowledge.

Close all open dialog boxes and return to the main AKT5 screen.

All knowledge in the knowledge base is represented by ***statements*** – we call these the ***basic units*** of the knowledge base. There are 4 different types of statement. ***Attribute statements*** tell you about the properties (attributes) of something – they are descriptive. ***Causal statements*** give you information about cause and effect relationships. ***Comparison statements*** compare the properties of two objects. ***Link statements*** represent any connections between objects that cannot be represented using the other statement types.

Please be aware that AKT5 automatically generates a natural language translation in stylised

English and that the same process will apply for conversion into the other languages that are represented as synonyms. This will be explained in the relevant sections below.

Object hierarchies

What we refer to as ***objects*** are words used to refer to material or conceptual things e.g. pests, soil, trees, birds, policy. ***Object hierarchies*** are another way of organising knowledge by arranging specific objects under more general headings (these also have to be object terms) e.g. *cola de pavo, cuernavaca, árboles_cuje* and *guaychipilin* are all types of tree classified as 'árboles_con_hojas_suaves' (soft leaved trees) by farmers. Therefore, *cola de pavo, cuernavaca, cuje trees* and *guaychipilin* are all subobjects of the object 'árboles_con_hojas_suaves'. 'Árboles_con_hojas_suaves' is, then, the superobject of *cola de pavo, cuernavaca, árboles_cuje* and *guaychipilin*. Object hierarchies are similar in structure to topic hierarchies.

From the tool bar on the main AKT5 screen select '**Object Hierarchies**' from the '**KB**' drop down menu.

On the left you will see a list of the object hierarchies in the knowledge base. From this list, select '**árboles_con_hojas_suaves**'. On the right a dialog box will appear and you will see a column containing a list of all the '**Objects in Hierarchy**'. To the right of this you will see '**árboles_con_hojas_suaves**' highlighted as the '**Object**' and immediately below are the '**Immediate SubObjects**'.

Click on '**View Tree**' and you will be shown the full object hierarchy with *all* its 'subobjects'. Click on **Close** to go back to the previous window.

Now select '**árboles_cuje**' (cuje trees) from the '**Objects in Hierarchy**' list. You will see that this term appears in the '**Object**' box with '**árboles_con_hojas_suaves**' specified as the '**SuperObject**' above it and *cuje, cuje caspirol, cuje cushin, cuje grande* and *cuje paterna* specified as the '**Immediate SubObjects**' below it.

Close all dialog boxes.

Formal Terms

Formal terms are the key components of statements. They are essentially singular words or words strung together. ***Objects*** (as described above) are one type of formal term. Other types of formal term include ***actions*** – activities with a human agent, e.g. harvesting or planting, and ***processes*** – activities without a human agent, e.g. decomposition or germination. You will notice that underscores e.g. árboles_cuje, are used to connect two words to make a single formal term in AKT5. Terms which require a capital letter or number are put in inverted commas e.g. 'April' and '2_metros'.

Go to the toolbar on the main AKT5 screen and select '**Formal Terms**' from the '**KB**' drop down menu**.**

Click on the downwards arrow and scroll down the '**Type**' menu to see the different types of formal terms within the Kb. Select '**object**'. All the objects in the knowledge base are now listed. Scroll down and get an idea of the objects in the knowledge base.

Highlight '**árboles_cuje**' and select '**Details**'. This tells you what '**árboles_cuje**' is – the most common shade tree found on coffee plantations in the research communities.

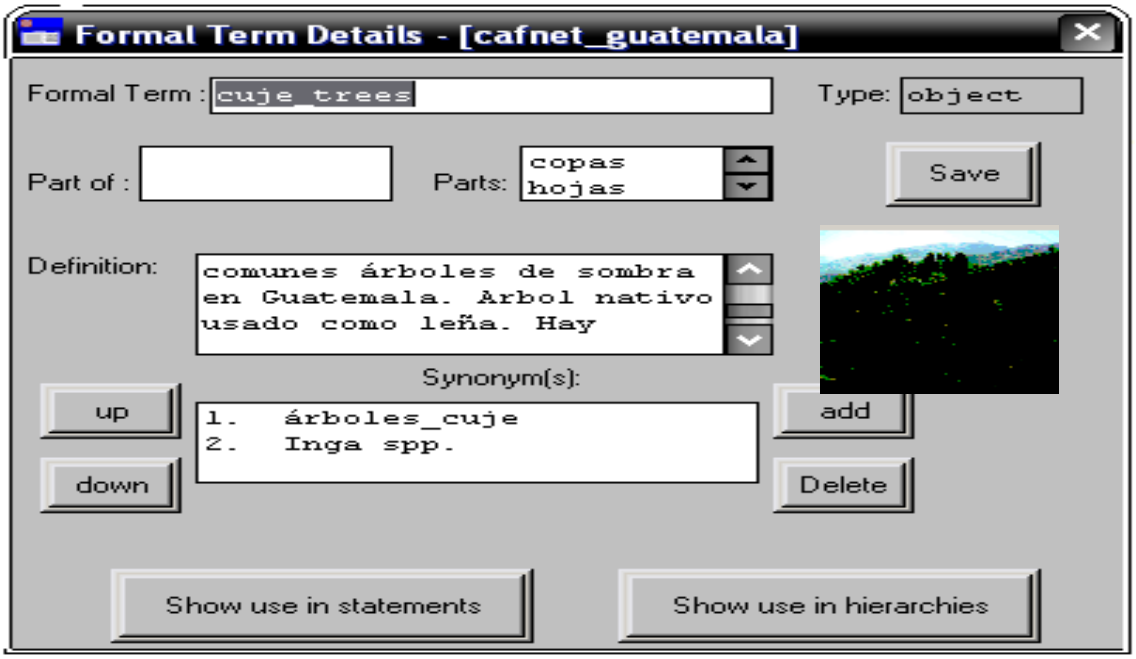

Figure 4. The 'Formal Term Details' box provides a brief description including information on the type of formal term, definition, synonym and a thumbnail photograph (if one is available). You can click on the thumbnail to enlarge the picture to see it more clearly.

Understanding the 'Formal Term Details' box (Figure 4)
Part of: This dialog box shows if the formal term is a part of something else (e.g. leaves are a part of trees)
Parts: This shows if a formal term has parts that are represented in statements. In the example given above there are statements about the part 'copas' of cuje trees.
Definition: Provides further information about the formal term.
Synonyms: Lists the synonyms attached to a specific formal term. During knowledge base development in Guatemala, the standard practice has been to include the first synonym as the Spanish translation. The second synonym is the scientific name. Where possible all plants and animals have scientific names entered as their synonyms because of the differences possible in local terminology. In the case of no English equivalent, the Spanish term is used.

Now select '**Show use in hierarchies**'. You will see that '**árboles_cuje**' appears in many object hierarchies (Figure 5). Select **OK**.

WIN-PROLOG
cuje_trees is a member of the following object hierarchies
todos_los_árboles , árboles_con_pocas_raíces , árboles_cuje , árboles_de_hojas_suaves , árboles_frescos , árboles_perenes , árboles_que_pierden_hojas , árboles_usados_para_leña
OK

Figure 5. Object hierarchy details of formal term.

Click on '**Show use in statements**'. The 12 statements that appear are all the statements in the knowledge base that mention the term '**árboles_cuje**' (excluding its subobjects).

Introduction to Diagrams

Diagrams are a way of representing interacting statements. However, only ***causal*** and ***link*** statements can be represented diagrammatically. One statement is represented by two ***nodes*** (a rectangular or oval box) connected by an arrow. The different colours and shapes of the boxes indicate different types of node – action, process, object and attribute nodes. The words written within the nodes are key terms used within the statements. The arrows represent the linkages between nodes. It is possible to view diagrams in either English or another language (when using the '**transpose_formal_terms_and_synonyms (Kb, Position)**' tool) with the latest version of Windows 2000.

Repeat the process outlined above to show the '**Formal Term Details**' of the object '**hojas**' (leaves).

Then, select **'Show use in statements**' within the '**Formal Term Details**' box. Click on '**All Statements**', shown under the '**Diagram Selection Type'** at the bottom of the formal term details dialog box.

The diagram that is generated will show you all the statements containing '**hojas**' that are able to be represented diagrammatically ('**causal**' and '**link**' statements).

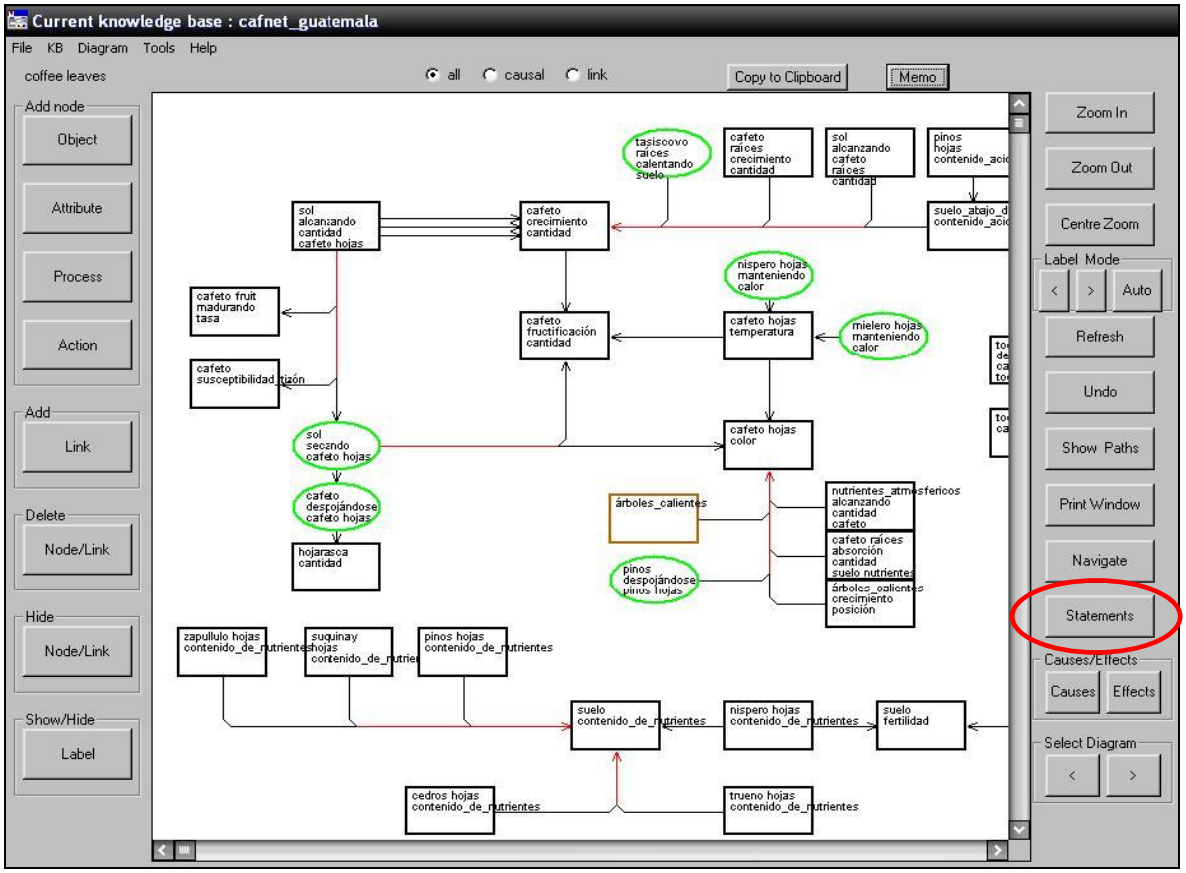

Figure 6. 'Hojas' diagram.

If you want to find out more about what is being said by a node, e.g. 'hojas de níspero que mantiendo el calor', you can click on the '**Statements**' button (circled in Figure 6 on the right) to get a list of all the statements represented in the diagram. Then select the relevant statement (in this case no. 57) and click on '**Details**'. From doing this, you will see a dialog box that contains the natural language statement at the top and the formal language equivalent at the bottom (Figure 7).

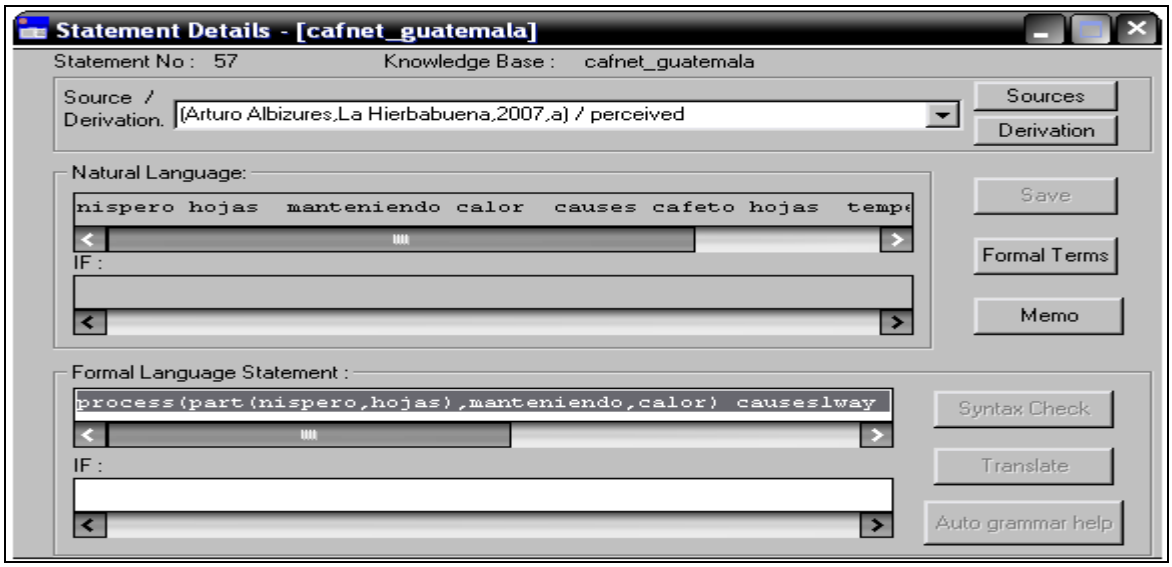

Figure 7. Statement details dialog box.

Now click on '**Formal terms**', select '**nispero**' and then click on '**Details**'; this will give you an explanation of the selected formal term. **Close** all the dialog boxes to return to the diagram.

Statements are typed into the knowledge base as ***formal language statements*** using a formal grammar (like a code) specific to AKT5. The AKT5 program translates the ***formal language statements*** into stylised natural language equivalents. Because of this computer generated translation, some statements in the knowledge base do not sound like natural English.

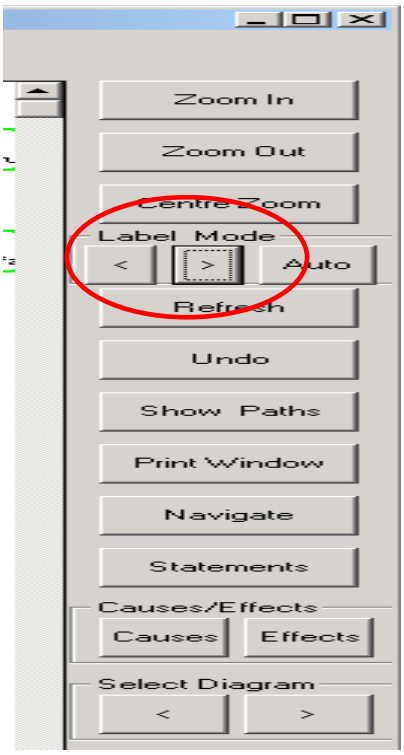

Figure 8. Diagram options.

Diagram options

Click once on the '**Label Mode**' button (circled in Figure 8). This will then show arrows that indicate causal relationships between nodes.

Click twice on the '**Label Mode**' button. This gives you the statements written on the diagram in full. You can make the statements more legible by using your mouse to drag the nodes across the screen to separate them out.

When working with complex diagrams it can be too confusing if all labels are pictured. Turn the label mode off by clicking a third time on '**Label mode**'.

By clicking on the '**Zoom Out**' button you will be able to see all the nodes that have been generated by the diagram. You can then click on '**Zoom In**' to restore the diagram to its original view.

Click first on '**Navigate**' and then a node (in this case, click on '**cafeto crecimiento cantidad**'); this will generate the immediate causes and effects of that node. The selected node will be highlighted in green and additional nodes will appear connected to it. Carefully drag sideways all new nodes to reveal any further nodes underneath (by pressing the left-hand mouse button over the node and dragging the node away). Red lines indicate that there is more then one line or arrow on top of one another.

If you select '**Show KB Diagrams**' from the '**Diagram**' drop down menu on the main toolbar (top of the screen), you can look at diagrams that have been organised previously. Alternatively, diagrams can be browsed by clicking on the buttons underneath '**Select Diagram**'.

When you have finished, go to the main toolbar (top left-hand corner) and select '**Hide Diagrams**' from the '**Diagram**' drop down menu. This will return you to the main AKT5 screen.

Boolean Search

Go to the main toolbar (top left) and select '**Boolean Search**' from the '**KB**' drop down menu. You will see '**Display Kb terms of type**' in the top left-hand corner of the dialog box with '**formal terms and sources**' underneath it. Click on the downwards arrow next to '**formal terms and sources**', scroll down and select '**object**'.

Select '**suelo**' (Spanish for soil) from the '**List of existing terms in Kb of the specified type'** and click on '**Details**' to see the definition and/or synonym of that formal term. Then **Close** the '**Formal Term Details**' dialog box by clicking on **X** and this will take you back to the '**Boolean search dialog box**'.

While the same term is highlighted, click on '**Select**' and '**suelo**' will appear in the '**Boolean Search String**' at the bottom of the dialog box. Then press the '**AND**' button under '**Boolean options**'. Now highlight '**nivel_de_humedad**' (an attribute) and click on '**Select**' once more. The search string will now have '**suelo and nivel_de_humedad**' as its search criteria (Figure 9).

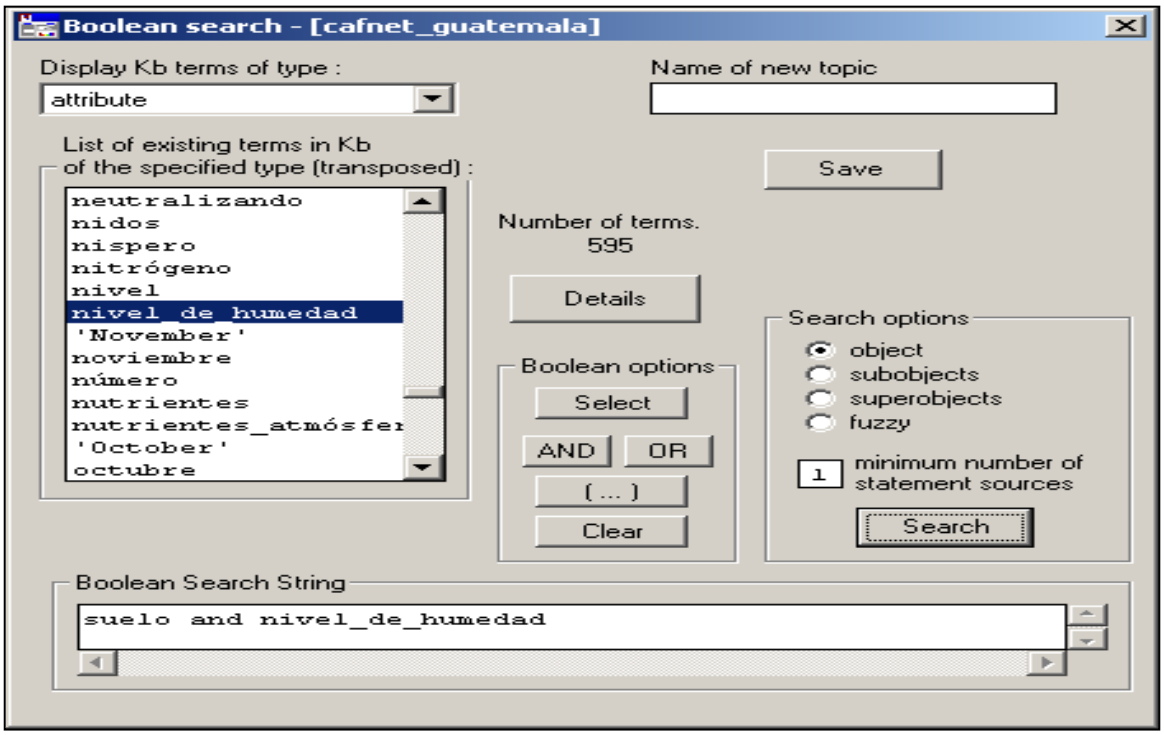

Figure 9. Boolean search dialog box.

When ready, click on '**Search**'. 31 statements will appear. These are the only statements in the knowledge base which include both '**suelo**' *and* '**nivel_de_humedad**'.

Boolean search options

There are a variety of '**Search options**' you can choose from (Figure 9). You can select to include '**subobjects**', '**superobjects**' and '**fuzzy**' in the search. '**Fuzzy**' makes sure search terms that have prepositions in statements are included, e.g. '**into_soil**'.

You can also filter statements according to the number of sources attached to the statements. For example, if you only want to pull up statements with at least three sources attached to them, you enter '3' into the box next to '**minimum number of statement sources**'.

Close the '**Search results'** dialog box by clicking on **X**. In the '**Boolean search**' dialog box select '**Clear**' under '**Boolean options**' to delete the search string.

Select the same terms again, '**suelo**' and '**nivel_de_humedad**', but this time select '**OR**' instead of '**AND**' from the '**Boolean options**'. Then, click on '**Search**'.

Now you will have 132 statements. This is because you have selected all the statements that include either '**suelo**' *or* '**nivel_de_humedad**'.

Close the '**Search results'** dialog box by clicking on **X**. In the '**Boolean search**' dialog box keep '**suelo**' in the '**Boolean Search String**' but this time select '**subobjects**' in addition to '**object**' under '**Search options**' (Figure 10). Click on '**Search**' once more.

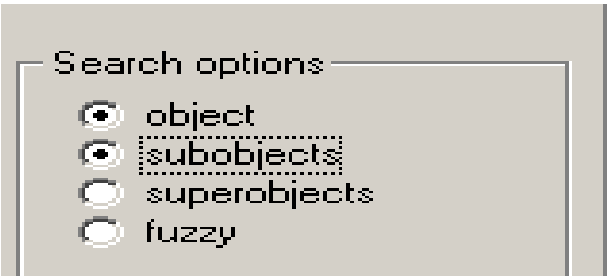

Figure 10. Search options dialog box.

You will now have 135 statements because, besides the statements that include the term 'suelo', you have also selected statements that relate to the subobjects of 'suelo'. The different types of soil as identified by farmers were 'barrial' (clay soil), 'suelo_blanco' (white_soil), 'suelo_acido' (acid soil) and 'suelos_negros' (black soil).

Close all the dialog boxes by clicking on **X.** This will return you to the main AKT5 screen.

Closing a Knowledge Base

Close the knowledge base by going to the main toolbar and selecting '**Close Kb**' from the '**KB**' drop down menu. **Close** AKT5 by selecting '**Exit from AKT5**' from the '**File**' drop down menu.

4. Exploring the knowledge base: some highlights from local knowledge

From practicing with '**A quick sightseeing tour'**, it should now be possible to explore the knowledge base more thoroughly. Some of the initial findings from the local knowledge research have been introduced below to help develop your skills in navigating around the knowledge base, as well as add a bit more context to the research findings. Tools that can aid your exploration of the knowledge are given, where relevant, at the end of each section (some of these are explained in Appendix 1).

Section 4.1 explores coffee farmers' classification of trees in the research area of El Hato Watershed and links the attributes of trees with ecosystem services, according to how farmers utilised and understood the trees they had on their coffee plantations.

Section 4.2 looks at interactions between faunal and floral species within coffee farms and the value of vertical complexity within coffee agroforesty systems, as well as across strata.

Section 4.3 takes into consideration species differentiation across the coffee growing landscape and farming practices that were related not only to altitude but also to microclimatic conditions that were influenced by a range of factors according to farmers.

Section 4.4 summarises farmers' knowledge about tree species' impacts on soil stability and water sources; the information was pulled out from the knowledge base and enhanced by tables developed outside of AKT5.

Section 4.5 shows the relationship between coffee productivity and agroforestry practices and indicates some of the short and long term trade-offs that were evident on many of the coffee plantations in EL Hato Watershed. Abundance of particular tree species was not simply reliant on the number of 'services' a tree could provide; it was dependant on weightings of services according to individual farmers.

4.1. Local classification of trees and their attributes

The coffee farmers in EL Hato Watershed had a complex classification system of trees according to physical attributes and the impacts the trees were observed to have when intercropped within coffee plantations. Many trees were utilised for a specific purpose by farmers (i.e. food, timber, fuelwood, shading coffee) but were also observed to impact on the environment in various ways that were secondary to the primary purpose.

4.1.1 Discussion of ecosystem services table

Table 3 shows the ecosystem services that were directly attributed to a sample of the most and least common trees found in the research sites[5]. The most common trees were largely considered to have a more positive effect on ecosystem service provision than the least common, but it is important to mention here that not all 'services' should be regarded as having the same weighting for coffee farmers (discussed in more detail in section 4.4)

[5] A full list can be found in Appendix 3.

Table 3. Ecosystem services table showing a sample of the most common and the least common shade trees, with their associated 'provisioning services' and 'regulating services', as described by coffee farmers in El Hato Watershed.

Presence within farm	Tree species	Provisioning services					Regulating services				
		Nutrient cycling	Soil formation	Food source	Firewood/ timber	Medicinal	Water regulation	Climate regulation	Soil stability	Disease and pest regulation	Pollination
Common species	*Coffea arabica**	-	0	+	+	0	0	0	+	-	+
	Inga spp.	+	+	0†	+	0	+	+	+	0	+
	Musa spp.	0	+	+	0	0	+	+	+	0	0
	Chamaedora tepejilote	0	0	+	0	0	0	0	+	0	0
	Eryobotria japonica	0	0	+	0	0	0	+	+	0	+
Less common species	*Trema micrantha*	0	0	+	0	0	+	0	0	0	+
	Cedrela tonduzii	0	0	0	+	0	+	0	0	0	0
	Solanum bansii	0	+	0	0	0	0	+	0	-	0
	Psidium guajava	0	+	+	+	+	0	0	0	0	0
	Citrus sinensis	-	0	+	0	+	0	0	0	0	+

Key: (**0**) indicates a neutral effect on the service indicated, (+) indicates a positive effect on the service indicated, (-) indicates a negative effect on the service indicated.

* The role and classification of coffee according to farmers was not as a tree, it was placed in this table just to show how it compares with the shade trees it is intercropped with in terms of ecosystem service provision.

† Many species of Inga have edible fruits, but they were not considered a food source because the fruits were not part of the farmers' diets.

Despite their differences, both cuje trees (*Inga* spp.) and pacaya (*Chamaedora tepejilote*) were very common within coffee plantations. Although pacaya is shown to have a lower positive value than *Inga* spp. in Table 3 (a difference of five '+'), it was regarded by farmers as an important food source and did not compete heavily with coffee. Pacaya's primary 'service' as a food source had the ability to override the lack of additional services; indicating that only looking at the number of 'services' provided by trees can be misleading when considering factors influencing species abundance. The number of 'services' provided by shade trees needs to be understood in relation to the local weighting of such 'services'.

In terms of animal species (the diversity of which can have a vital impact on pest control), banana fruits, as much as cuje tree fruits, were highly sought after by mammals and birds as a food resource. Farmers also said that the flowers of cuje trees attracted hummingbirds and bees that were regarded as useful pollination species. Due to its growth rate, bananas were frequently used as an initial shade species while cuje trees were being established within coffee plantations. In more established plantations it was common to find cuje trees mixed with banana species, although the former were generally more abundant than the latter.

The abundance of different tree species in coffee plantations was largely influenced by the tree species' interaction with coffee productivity, and whether it impacted negatively or positively on a farmer's livelihood. As their major source of cash income, coffee was the main concern of farmers and trees that had the potential to negatively affect coffee productivity were the least desired shade trees.

4.1.2 Shade tree classifications

Many trees were classified according to the shade quality they had the potential to provide for coffee; there were 'fresh trees' ('árboles frescos') and 'caliente trees' ('árboles calientes'), largely specified by farmers as having good and bad shade tree attributes. 'Fresh' and 'caliente' trees were positioned at the opposite ends of a spectrum and there were trees that did not fit into either classification system because of their more neutral impacts on coffee. Canopy type, leaf and root texture, and amount of roots were all attributes that determined which trees were termed as 'fresh' or 'caliente'. There was a mixture of all these trees across coffee plantations, depending on farmers' livelihood needs and whether particular tree attributes outweighed others in relation to these needs.

Fresh trees were the highly desirable shade trees, being perceived as providing ideal microclimate conditions for coffee growing. The most common species described by coffee farmers were cuje (*Inga vera*), cuje caspirol (*Inga laurina*), cuje cushin (*Inga oerstediana*), cuje grande (*Inga edulis*) and cuje paterna (*Inga jinicuil*). These species were classified by farmers as 'cuje trees' (Figure 11) and were considered to be highly positive in terms of both provisioning and regulating services within coffee farms (with seven '+' in Table 3).

Bananas (*Musa* spp.) were also 'fresh trees' and were often grown on coffee plantations, acting as an important food source, providing shade for coffee, and helping to control soil erosion. The main species of banana mentioned by farmers were banana, banano majunche, banano manzanito, guineo, guineo habanero amarillo and guineo habanero

morado (Figure 11). There was shown to be a good understanding of the ecosystem services provided by banana species, with many positive impacts described by farmers.

Although the majority of trees that fitted into this category were used as shade trees, not all fresh trees were used for shade in coffee plantations. An exception was amate (*Ficus glabrata*) because its crown was deemed too dense and it was thought that coffee plants grown under this tree would be subject to more humidity than required. Amate was only found on coffee plantations if it had grown due to natural regeneration or it had been there before the coffee plantations had been established (in this case it could be more damaging to remove the tree than leave it).

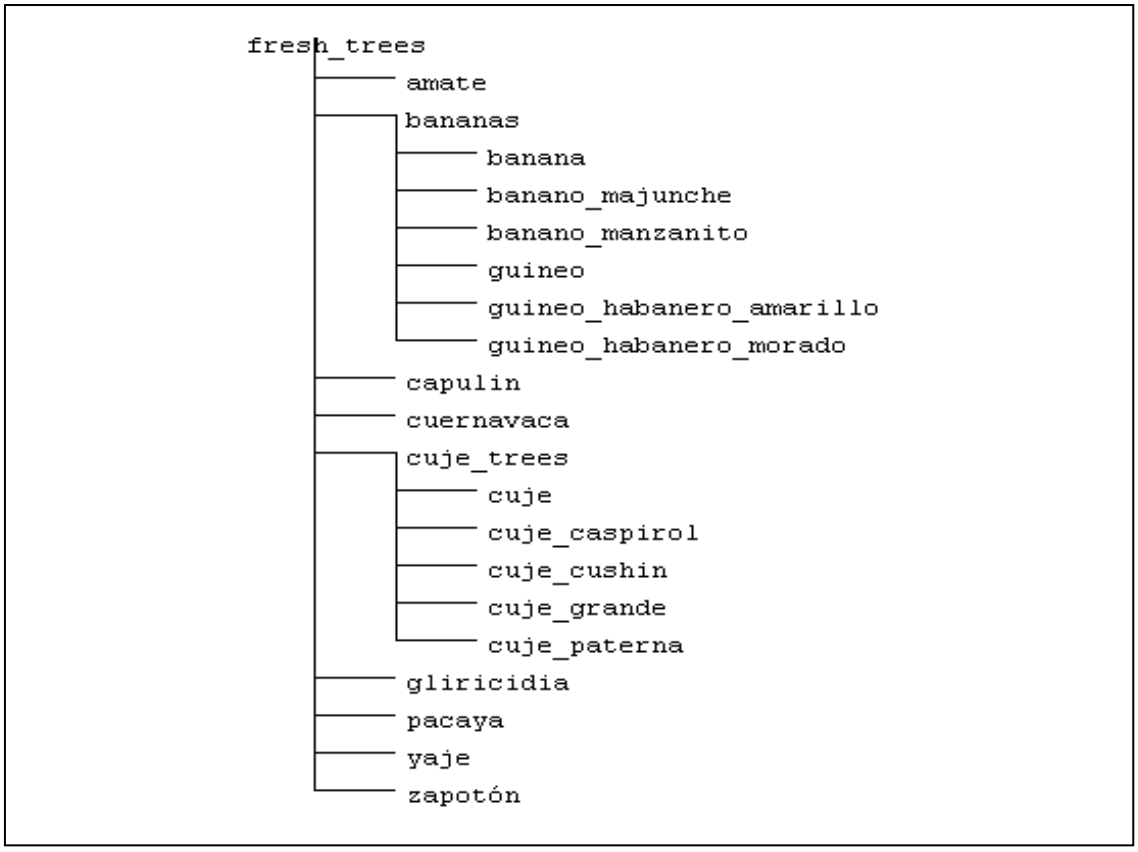

Figure 11. Shows the 'fresh trees' object hierarchy with its subobjects of bananas and cuje trees.

Cuje trees and banana trees were the most common shade trees within coffee plantations and this was because they both had many desirable characteristics; they were stated to be relatively easy to manage in terms of reproducing, planting, growing, and pruning. Organic matter obtained from cuje trees leaves was considered useful in different ways: they were said to increase the fertility of the soil, reduce the amount of weeds and therefore decrease labour requirements. Furthermore, the shading of coffee plants by cuje trees were thought to be beneficial due to humidity regulation, protection against rainfall, sun and fog. Effective management of shade was observed to be a major factor of influence upon two important drivers of coffee productivity: the severity of fungal diseases and the yield of coffee fruits.

Even though cuje trees were not considered as providing the best firewood, the use of it for this purpose was still evident and people considered it a beneficial species because of this. Likewise, banana species were observed to have a very high impact on farmer

livelihoods because their fruits were widely and heavily consumed. Although organic matter obtained from banana leaves was not considered as good as that from cuje tree leaves, banana leaves were said to have the advantage of an easy to cut stem when they fell and this was used as a barrier to avoid soil erosion and/or just to increase soil organic matter. Both banana and cuje trees were classified as fresh trees partly because of having roots that reduced soil erosion and contributed to soil having a good moisture content for coffee growing.

Caliente trees were generally perceived as bad shade trees for coffee because of their negative impacts on the crop, causing a decrease in the health of coffee plants - observed by farmers as the amount and colour of the leaves and the yield of the plants. Timber quality was an additional attribute that was used to classify trees as 'caliente', besides canopy type, leaf and root texture, and amount of roots. Despite the negative impacts they often had on coffee productivity, these trees were often found on coffee farms in low abundance. The main reason for keeping 'caliente trees' (Figure 12) was for the provisioning services they could provide, mostly in the form of timber and fuelwood.

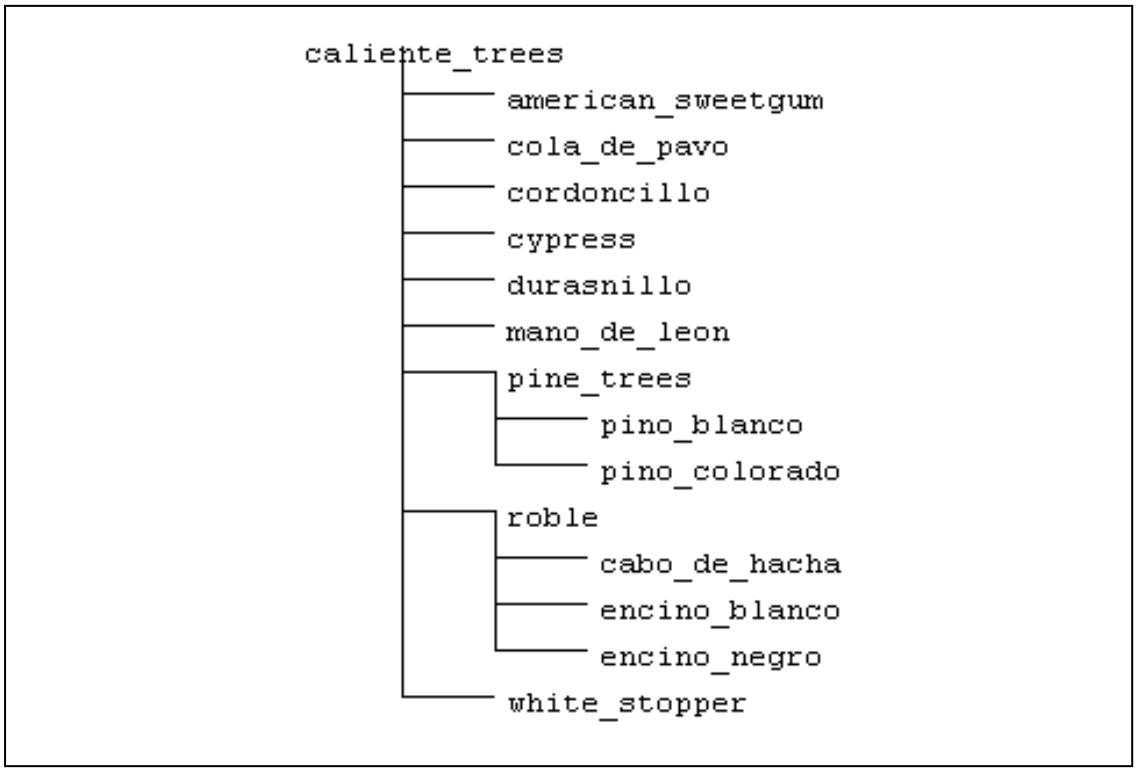

Figure 12. Shows the 'caliente trees' object hierarchy with its subobjects of cola de pavo, white stopper and pine trees.

Cola de pavo was used by some farmers as a temporary shade tree in coffee plantations while cuje trees were in the process of being grown as the main shade trees. This 'caliente' tree was primarily used because it was a fast growing tree and its branches could be utilised for building coffee nurseries. Likewise, tasiscovo (otherwise known as white stopper or *Perymenium grande*) was kept within coffee plantations even though it was said that it did not support coffee growth; this tree was used for its wood in making fences and wooden posts. Pine trees (*Pinus* spp.) were also 'caliente trees' that could be found on some farms, grown for their valuable timber.

Medium trees is given as a term for the trees that farmers did not classify as either 'fresh' or 'caliente'. These trees were also used as shade trees but were neither strongly positive nor negative in their effects upon coffee productivity. Palma (*Sabal mexicana*) and nispero (otherwise known as loquat or *Eryobotrya japonica*) can both be given as examples of this type of tree that was found in relative abundance on coffee plantations; they were stated as not providing ideal conditions for coffee plants but neither where they causing negative effects. They also had an impact on farmer livelihoods because they both provided a food source, and palma leaves were used as building material.

4.1.3 Summary

There are many object hierarchies within the knowledge base that collect together knowledge about trees and their attributes, and many of the classifications are opposites of another, e.g. 'fast growing trees' and 'slow growing trees'; 'small leaf trees' and 'large leaf trees'; 'dense crown trees' and 'sparse crown trees'. Farmers were classifying trees according to observable differences and the agro-ecological interactions as a result of such attributes. Through understanding these classification systems, it is possible to see which trees are capable of providing particular ecosystem services and how farmers use them in the farming landscape.

Tools

Useful AKT5 tools:

- Cafnet tool 'hierarchic_objects_usage'. Can be used to see the object hierarchies that particular trees appear in.
- Knowledge evaluation tool 'object_hierarchies' (found in AKT5/Tools/System Tools/Knowledge Evaluation). Can be used to see the number of statements attached to each object hierarchy. It is vital to note that the number of statements does not indicate the level of utility that those statements might represent; there might be few statements of great utility in comparison to many statements of less useful knowledge.

4.2 Interactions between flora and fauna in coffee farms

Farmers described all the various taxa and species they identified as being from the coffee zone rather than the cloud forest areas. Forest species were said not to visit the coffee farms both because they were adapted to the cooler climate at higher altitude and due to the greater inhabitation by people in the cultivated areas. Aside from forest species, there were many animals (farmers used this term to mean mammals) and birds that foraged and nested in coffee farms in the research area. But, informants highlighted a decrease in certain mammal populations due to hunting, namely tepezcuintles (*Cuniculus paca*), deer, tacuasines (*Didelphis marsupialis*), mapaches (*Procyon lotor*), armadillos (*Dasypus novemcinctus*) and rabbits (*Oryctolagus spp.*); excessive hunting of tepezcuintles had led to them being classed as endangered.

Trees and understory plants within coffee farms were understood to attract particular species of animals, birds and insects to live and/or feed there; they were observed to take advantage of the various vegetative layers that coffee farms were composed of. Depending on farming practices, such habitat strata were observed to provide many nesting and feeding opportunities, as well as protection against predators (Plate 4). Although not discussed in terms of its role in maintaining and increasing biodiversity, farmers identified the preferred habitat for a number of species as being at a specific stratum (Table 4).

Plate 4. A bird nest at ground level in a coffee farm in Las Parcelas community. Photograph taken by Emma Martin, July 2007.

Table 4. Habitat strata within coffee farms.

Stratum	**Habitat features**	**Associated fauna**
Ground	Soil, stones, weeds, leaf litter, caves	Small birds, rodents, bats and snakes
Middle	Coffee plants and thickets	Small/medium birds and snakes
Upper	Tall trees	Large birds and squirrels

While different structural levels were said to provide habitat for different fauna, farmers recognised that other spatial features across strata within coffee farms were also important for particular species, with each feature providing a unique habitat. An example of this would be the thickets that grew on the edge of coffee farms; these were said to be used by species such as the paisana (also locally known as faisán – translates in English as pheasant).

Attributes of different trees were also observed to influence which species used them, for example, tasiscovo with its straight branches attracted squirrels (Kb statement no. 131) and mano de leon with its open crown was preferred by some birds because it meant they could fly from their nests easily (Kb statement no. 181). Farmers said that, in general, trees with dense crowns provided protection for birds against the elements and predators. They emphasised, however, that each bird or animal would have its own requirements and preferences, so dense crowned trees would not suit all. Phenological attributes of trees, such as timing of fruiting, were considered major factors in attracting mammals and birds to coffee farms throughout the seasons (Kb statements no. 136, 137 and 158), particularly if there was a high abundance of sweet fruits such as those of nispero, amate and capulin trees (Kb statement no. 586).

Farmers made general statements about birds (Figure 13), but they also had more detailed knowledge of where specific birds were nesting, amongst other creatures like squirrels and bees (Figure 14). From observations made on farms, coffee growers had behavioural knowledge about the majority of the birds and animals identified by them, including feeding patterns and habitat preferences, which also reflect interactions between fauna and flora species present in the landscape.

An important association was made between insect levels and bird population, with farmers stating that an increase in insect numbers leads to more birds visiting the coffee farms (Kb statement no. 420), and specific trees were mentioned as attracting more insects and, thus, birds (Kb statements no. 134, 176 and 272). Farmers further pointed to the role that birds themselves play in increasing tree diversity through bringing fruits and seeds from other coffee farms or from the forest, and contributing to natural regeneration and the establishment of new tree species.

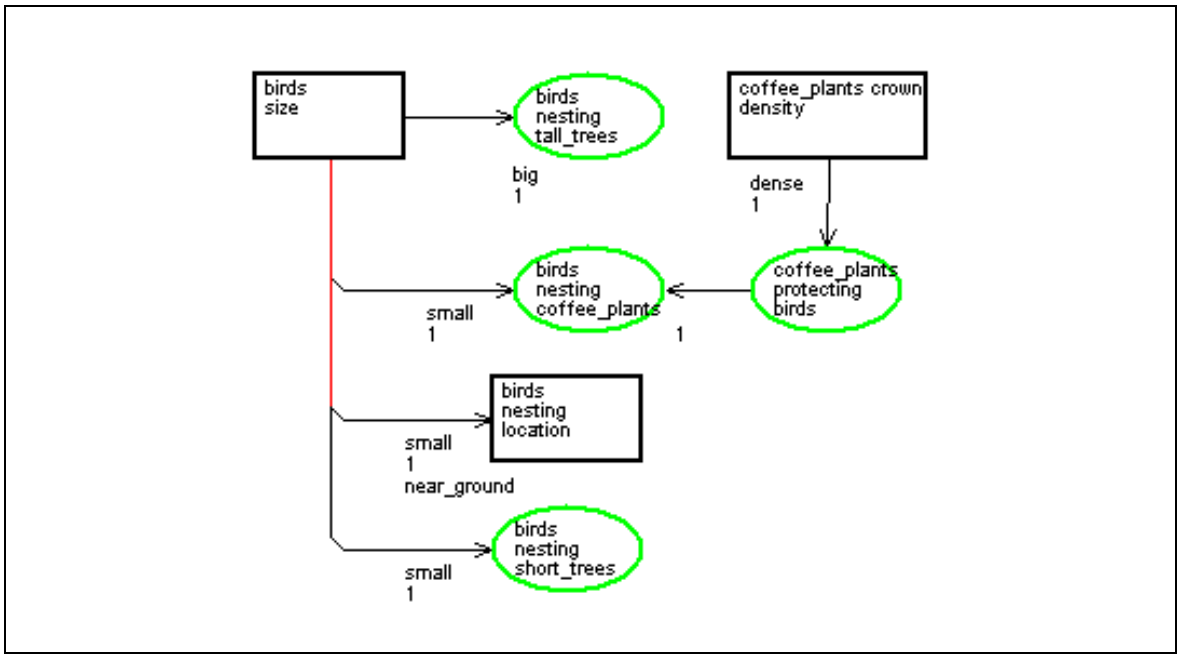

Figure 13. AKT5 causal diagram representing general statements about bird nesting locations in coffee farms. Nodes represent natural processes (ovals) or attributes of objects, processes or actions (boxes with straight edges). Arrows connecting nodes denote the direction of causal influence. The first small arrow on a link indicates either an increase (↑) or decrease (↓) in the causal node, and the second arrow on a link refers to an increase (↑) or decrease (↓) in the effect node. Numbers between small arrows indicate whether the relationship is two-way (2), in which case ↑A causing ↓B also implies ↓A causing ↑B, or one-way (1), which indicates that this reversibility does not apply. Words instead of small arrows denote a value of the node other than increase or decrease (e.g. when bird size is **small**, their nesting location is **near_ground**).

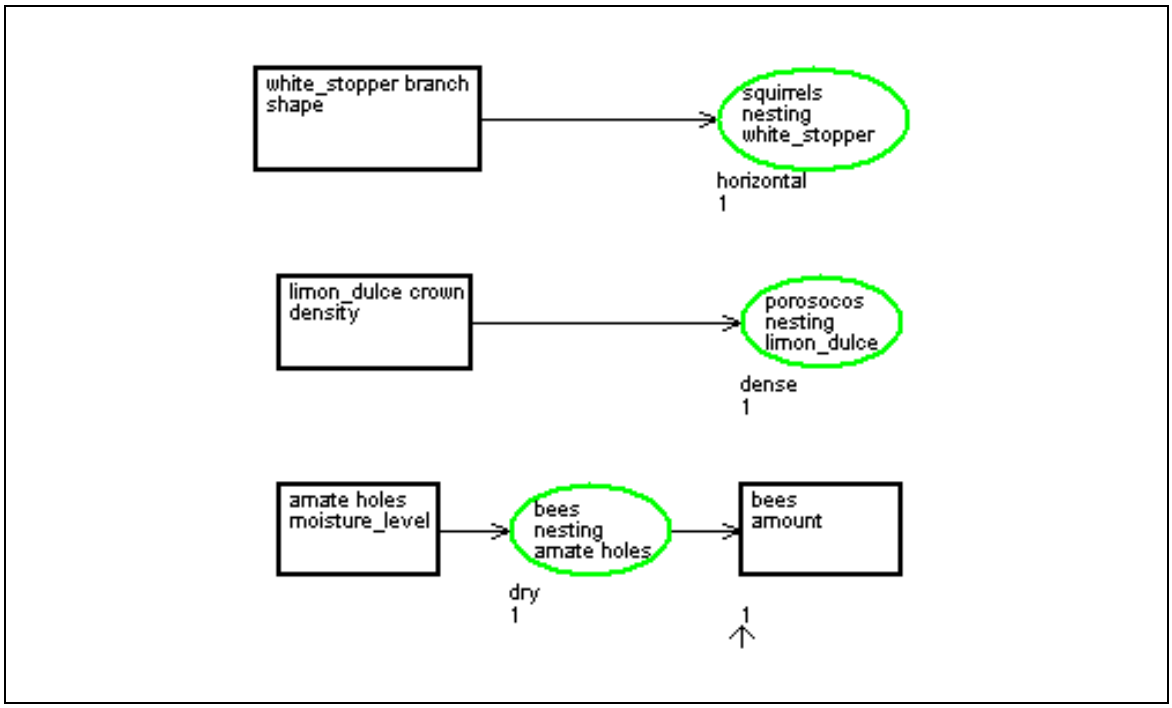

Figure 14. AKT5 causal diagram representing specific knowledge about interactions between species. Legend same as above.

4.2.1 Summary

When looking at associations between fauna and flora within coffee farms, it's important to consider which plants and trees attract which faunal species and the importance attached to maintaining or increasing these habitat features on farms. The fauna and floral species present on farms make up the ecosystem and, therefore, in assessing which species should be encouraged there needs to be a clear understanding of what 'services' people want from a coffee farm ecosystem.

Tools

Useful AKT5 tools:

- Cafnet tool 'hierarchic_objects_usage'. Can be used to see the object hierarchies that particular animals and birds appear in.
- Boolean Search tool (found under KB/ Boolean Search). Can be used to search statements that are attached to particular formal terms, sources and user values.
- Topics (found under KB/ Topics). Can be used to pull up statements that have been grouped together as topics, such as 'Phenology of tree and plant species', 'Habitat for birds' or 'Trees and insects'.

4.3 Trees as indicators of landscape change

Across the coffee zone of El Hato Watershed, farmers illustrated how their coffee farming practices differed throughout the year. The timing of specific management practices was related to climatic conditions, which was also affecting the abundance and growth of various tree species in the research communities. From talking to a local coffee technician and then gathering the information during interviews with farmers, the following Figure 15 was drawn up to show these differences.

Farmers' knowledge about the growth and attributes of specific tree species in different zones was not dependent on the communities the farmers were from. Because the low, medium and high areas were within a relatively close distance to one another (in some cases communities had farms located across different areas), the knowledge associated with these areas and their relationship with coffee farming was widespread. The knowledge farmers had of their own local area and other altitudinal ranges in terms of tree species abundance and growth is represented in Table 5.

4.3.1 Climatic conditions and farming practices

Altitude gradient was an important factor to take into consideration when talking about temporal aspects of coffee management within the El Hato Watershed; because of the variation in climatic conditions and vegetation that different farming communities were living with, farming practices were taking place across slightly different time spans (Figure 15).

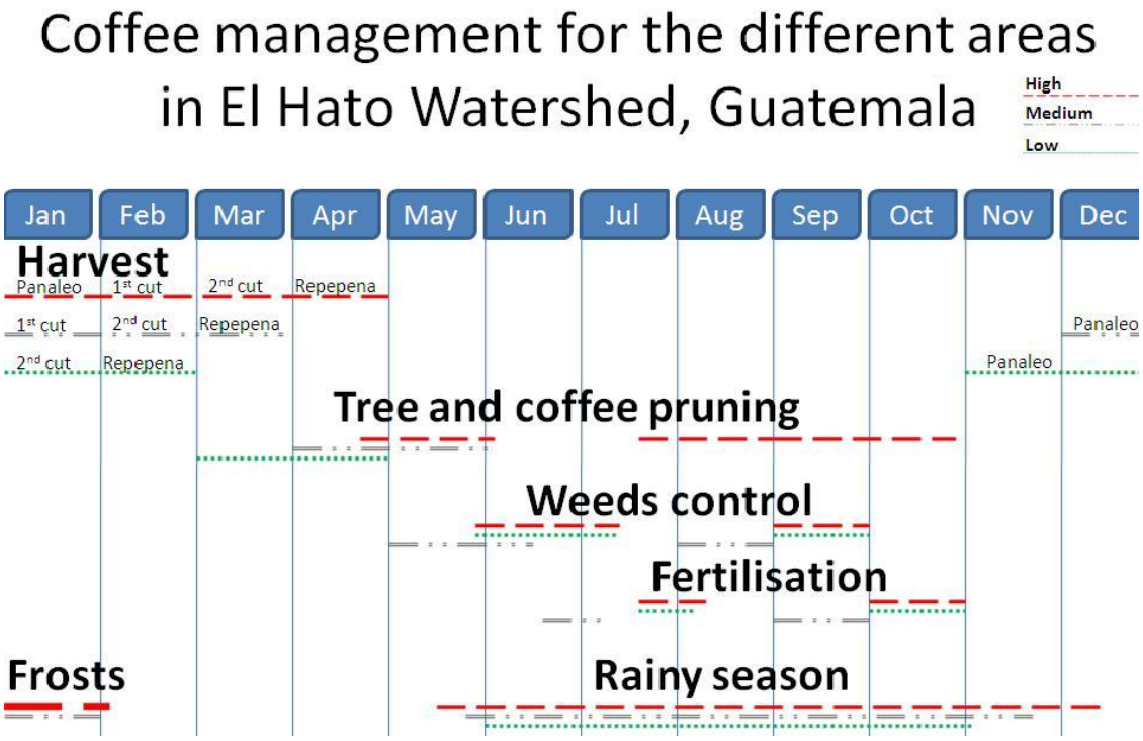

Figure 15. Showing coffee management variation across three identified areas within the coffee zone of El Hato Watershed. The low, medium and high areas were identified by a coffee technician and then confirmed during on-farm interviews when farmers gave details of their seasonal farming practices.

The altitude of the El Hato Watershed region was between approx. 300 meters to above 2400, at the head of the protected area, with the majority of coffee plantations situated between 900 and 1600 meters above sea level. This 'coffee friendly' altitudinal range

was found in an area of less than 15 kilometres, meaning that farmers could easily compare what was happening on their coffee farms to distinct neighbouring farms.

In a similar way to Holdridge (1967), coffee farmers made distinctions between agroecological zones (shown in Figure 15) and generally classified the surrounding area into four types: low areas where coffee did not grow, low areas conducive to growing coffee, high areas conducive to growing coffee, and high areas where coffee did not grow. However, these identified 'zones' should not be regarded as exclusive, because, overlapping the high and low areas where coffee was able to grow, some farmers recognised a 'medium' area. The farmers' description of coffee growing zones was closely related to altitude, but, there were more complex layers influencing why a farm would be regarded as being in a 'high', 'medium' or 'low' area. The location within the watershed and topography factors could be seen as influencing the weather patterns and these, combined with altitude, were creating the various climatic conditions that farmers were working under to produce coffee. A few examples can be given to show how topography can heavily influence a coffee plantation:

- If there is a mountain directly in front of a plantation then the amount of daylight hours will be reduced.
- If a plantation is on steeply sloped land, it will receive less sunlight than a plantation located on flat land.

The different climatic conditions apparent in the research area needed to be taken into account when looking at local agro-ecological knowledge because of the impact this was having on coffee management and, possibly, different species of plant and animal species found on farms. Farmers said that during the dry season the weather was hottest in low areas, and, to keep the coffee plants in a healthy condition, more shade and more organic matter was required in these areas to maintain moisture content of the soil. Shading of coffee was deemed to be less advantageous in high areas because of the level of cloud apparent in these places, but shade trees were still valued, particularly at specific times of the year. For example, at the end of the rainy season, shade trees were stated as helping to reduce the damage that coffee plants could suffer from frosts in the high areas.

Figure 15 shows how the rainy season was said to be spread across the months slightly differently in each area and indicates how these differences were influencing coffee management practices. The rainy season was finishing later in the high areas and because of this farmers were harvesting their coffee up to two months later than in the lower areas.

4.3.2 Climatic conditions and tree species variation

In addition to temporal variation of management practices, there were differences in abundance and presence of tree species that grew across the low, medium and high areas (Table 5). Many species were able to indicate transitions between agro-ecological zones, not necessarily just because of abundance but also how well they were growing in comparison to other areas. Some species were found in all areas but with abnormal features (e.g. fruit trees growing but not producing fruit) and some trees were having problems surviving and just a few individuals could be found.

Table 5. Differences in tree species according to high/medium/low areas within the coffee zone. This table represents all the trees present in the knowledge base that farmers gave information about in terms of their abundance and growth in different areas. The trees that lacked this information are given in the notes to this table.

Tree species		High zone		Medium zone		Low zone	
Spanish name	**Scientific synonym**	**Abundance**	**Growth condition**	**Abundance**	**Growth condition**	**Abundance**	**Growth condition**
Yaje ^	*Acacia acanthophylla*	Many	Good	Many	Good	Many	Good
Pacaya ^	*Chamaedorea tepejilote*	Many	Good	Many	Good	Many	Good
Limon puro	*Citrus aurantifolia*	Many	Good	Many	Good	Many	Good
Naranja ^	*Citrus sinensis*	Many	Good	Many	Good	Many	Good
Jocote	*Spondias mombin*	Many	Good	Many	Good	Many	Good
Suquinay ^	*Vernonia patens*	Many	Good	Many	Good	Many	Good
Guarumbo	*Cecropia obstusifolia*	Many	Good	Many	Good	Few	Good
Limon dulce	*Citrus paradisi*	Many	Good	Many	Good	Few	Good
Nispero	*Eryobotria japonica*	Many	Good	Many	Good	Few	Good
Cuje cushin	*Inga oerstediana*	Many	Good	Many	Good	Few	Good
Limon real	*Citrus limonia*	Many	Good	Many	Good	Few	Bad - less fruits
Pito	*Erythrina berteroana*	Few	Good	Few	Good	Many	Good
Amate	*Ficus glabrata*	Few	Good	Many	Good	Many	Good
Cuje grande	*Inga edulis*	Few	Good	Many	Good	Many	Good
Guayabo	*Psidium guajava*	Few	Good	Many	Good	Few	Good
Higuerillo	*Ricinus communis*	Few	Good	Many	Good	Many	Good
Izote	*Yucca elephantipes*	Few	Good	Many	Good	Many	Good
Banano	(Undefined)	Few	Bad - without fruits	Many	Good	Many	Good
Banano manzanito	(Undefined)	Few	Good	Many	Good	Many	Good

Guineo	(Undefined)	Many	Good	Many	Good		
Ceibillo	Ceiba aesculifolia	Many	Good	Many	Good		
Tasiscovo	*Perymenium grande*	Many	Good	Many	Good		
Pino blanco†	*Pinus maximinoi*	Many	Good	Many	Good		
Cordoncillo	*Piper adumcum*	Many	Good	Many	Good		
Palma	*Sabal mexicana*	Many	Good	Many	Good		
Cabo de hacha	*Trichilia americana*	Many	Good	Many	Good		
Cipres†	*Cupressus lusitanica*	Many	Good	Few	Good		
Guaychipilin	*Diphysa americana*	Many	Good	Few	Good		
Cuje	*Inga vera*	Many	Good	Few	Good		
Capulin comestible	*Muntingia calabura*	Many	Good	Few	Good		
Encino blanco	*Quercus peduncularis*	Many	Good	Few	Good		
Capulin†	*Trema micrantha*	Many	Good	Few	Good		
Zapotón	*Swietenia humilis*	Many	Good	Few	Good		
Naranjilla	*Zanthoxylum caribaum*	Many	Good	Few	Good		
Aguacate	*Persea americana*	Many	Good	Few	Bad - less/smaller fruits		
Chaperno	*Lonchocarpus minimiflorus*	Few	Good	Many	Good		
Encino negro	*Quercus sapotifolia*	Few	Good	Many	Good		
Matasano	*Casimiroa edulis*	Many	Good				
Cedro de montaña†	*Cedrela tonduzii*	Many	Good				
Gravilea	*Grevillea robusta*	Many	Good				
Cinco negro	*Lantana camara*	Many	Good				
Balsamo	*Liquidambar styraciflua*	Many	Good				
Durazno	*Prunus persica*	Many	Good				
Cuernavaca	*Solanum bansii*	Many	Good				
Cola de pavo†	*Cupania glabra*	Many	Good				

Mielero	Undefined	Many	Good				
Mandarina*	*Citrus reticulata*			Many	Good	Many	Good
Cuje paterna	*Inga jinicuil*			Many	Good	Many	Good
Banano majunche	(Undefined)			Many	Good	Many	Good
Guineo habanero amarillo	(Undefined)			Many	Good	Many	Good
Guineo habanero morado	(Undefined)			Many	Good	Many	Good
Pino colorado	*Pinus oocarpa*			Many	Good	Few	Good
Cedro	*Cedrela odorata*			Few	Good	Many	Good
Manzana rosa	*Syzygium jambos*			Few	Good	Many	Good
Madre cacao*	*Gliricidia sepium*			Few	Good	Many	Good
Mango*	*Mangifera indica*			Few	Bad - less/smaller fruits	Many	Good
Chico zapote*	*Manilkara zapota*			Few	Bad - less fruits	Many	Good
Aguacatillo	*Persea schiedeana*			Few	Bad - less/smaller fruits	Many	Good
Durasnillo	*Colubrina guatemalensis*			Many	Good		
Mano de leon	*Dendropanax arboreus*			Many	Good		
Caulote	*Guazuma ulmifolia*					Many	Good
Cuje caspirol	*Inga laurina*					Many	Good
Chupte	*Saurauia laevigata*					Many	Good

^ These trees were said to also be present at regions lower than the coffee zone.

† These trees were said to also be present at regions higher than the coffee zone.

Notes: Zapote (*Calocarpum pachecoana*), arrayán (*Myrica cerifera*), anono (*Annona squamosa*), sandillo (undefined), jicarero (undefined), izote pony (undefined), frijolillo (undefined) and trueno (undefined) were trees that lacked growth and abundance information.

Trees were not generally classified by farmers according to their usual growing range. All of the tree classifications (represented as object hierarchies) in the knowledge base were applicable for high, medium and low areas. For instance, 'stiff leaf trees' were all the species that had leaves with a hard texture, requiring a lengthy decomposition time in order to produce organic matter that was enriching for the soil. Some of these trees exclusively grew in the high areas, for example, cedro de montaña (otherwise known as mountain cedar or *Cedrela tonduzii*); some only in high and medium areas, for example, pino blanco (*Pinus maximinoi*); and, others grew in all the three areas, such as jocote (*Spondias mombin*). There were also some species that were said to grow in greater abundance in two of the areas and with less presence in the third; two of these tree species were guarumbo (*Cecropia obstusifolia*) and nispero (*Eryobotria japonica*), they were both common in the high and medium areas but far less would be found growing in low areas (Table 5).

Farmers understood that altitude was not the only factor influencing tree species composition across different areas; they also recognised that land use and vegetation type was a factor that encouraged the presence of specific species. Some tree species were stated as not being able to grow in primary forest but could grow in coffee plantations. For instance, amate (*Ficus glabrata*), capulín comestible (*Muntingia calabura*) and cola de pavo (*Cupania glabra*) were not able to grow in the forest areas but were able to naturally regenerate within coffee plantations (particularly if herbicides were not applied to control weeds). Alternatively, zapotón (*Swietenia humilis*) was mentioned as a species that was not able to grow within coffee plantations, instead being found near streams.

4.3.3 Summary

In looking at coffee farming practices, it is important not to apply blanket generalisations to a region but to recognise the different conditions farmers might be facing in terms of climate and species management. As can be seen, coffee farmers in the research area recognised that there were slightly different timings for particular seasons and farming activities, depending on the location of the farm. Not only was altitude a consideration but topography and vegetation also played a role in creating microclimatic conditions that varied between communities.

4.4 Coffee plantation composition, soil stability and water provision

Water regulation services were often associated with trees on farms and were frequently mentioned by the farmers. Such services consisted of processes such as reducing soil erosion, maintaining soil moisture content and humidity, and protecting water sources. Knowledge about these aspects is gathered together under a topic hierarchy called 'Trees and water infiltration' in the knowledge base (Figure 16), with 117 statements attached to it that demonstrate the various interactions between coffee plants, soil, trees and water as articulated by coffee farmers.

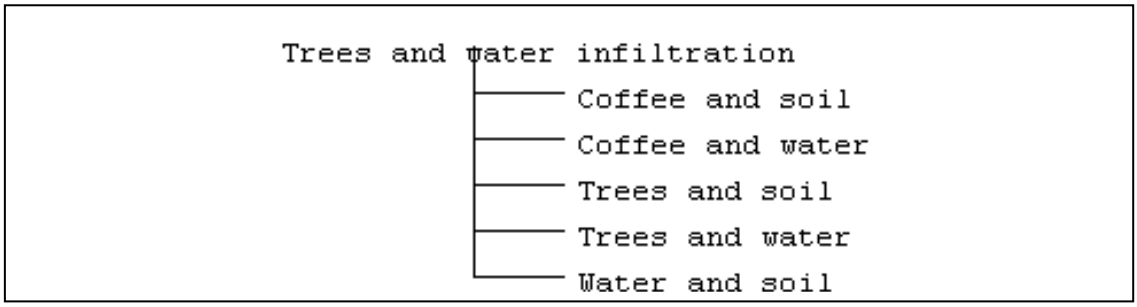

Figure 16. Topic hierarchy of 'Trees and water infiltration' as it exists within the knowledge base.

Across the El Hato watershed, farmers managed the trees within their coffee plantations in different ways. Farmers in low areas kept a higher number of shade trees, and the level of pruning was less than in upper areas (particularly in the case of *Inga* spp.). Low level pruning was carried out to keep soil moisture at a level conducive for coffee growing during the dry season; high level pruning would let too much sunlight penetrate the canopy and dry the soil (Figure 17). Farms in higher areas were pruning their shade trees more severely, in order to decrease the likelihood of fungal diseases occurring (Plate 5).

Plate 5. Severe pruning of *Inga* spp. on a coffee plantation in El Carmen community, a high area. Photograph taken by Carlos Cerdán, August 2008.

At a farm scale, farmers did not plant trees in a particular way to exploit their ability to draw water up from deep in the ground or help rain water infiltrate the soil. However, they were very careful in the case of trees around natural springs and streams and often left the trees alone that naturally grew in those locations. Farmers had detailed knowledge of the specific species that were useful for protecting water sources (represented in Table 6).

Farmers knew that if they wanted to enhance water provisioning services they should keep shade trees within coffee plantations, and reduce the severity of pruning the shade trees. They were very clear in their thinking that cutting down trees in order to establish any kind of crops would reduce water provisioning services. Undergrowth was not encouraged in coffee plantations for water provisioning or soil stability; ouilete (*Solanum nigrescens*) and chípilin (*Crotalaria longirostrata*) were the two main weeds kept within plantations, but they were kept because of their edible properties and not for any reason related to soil or water services.

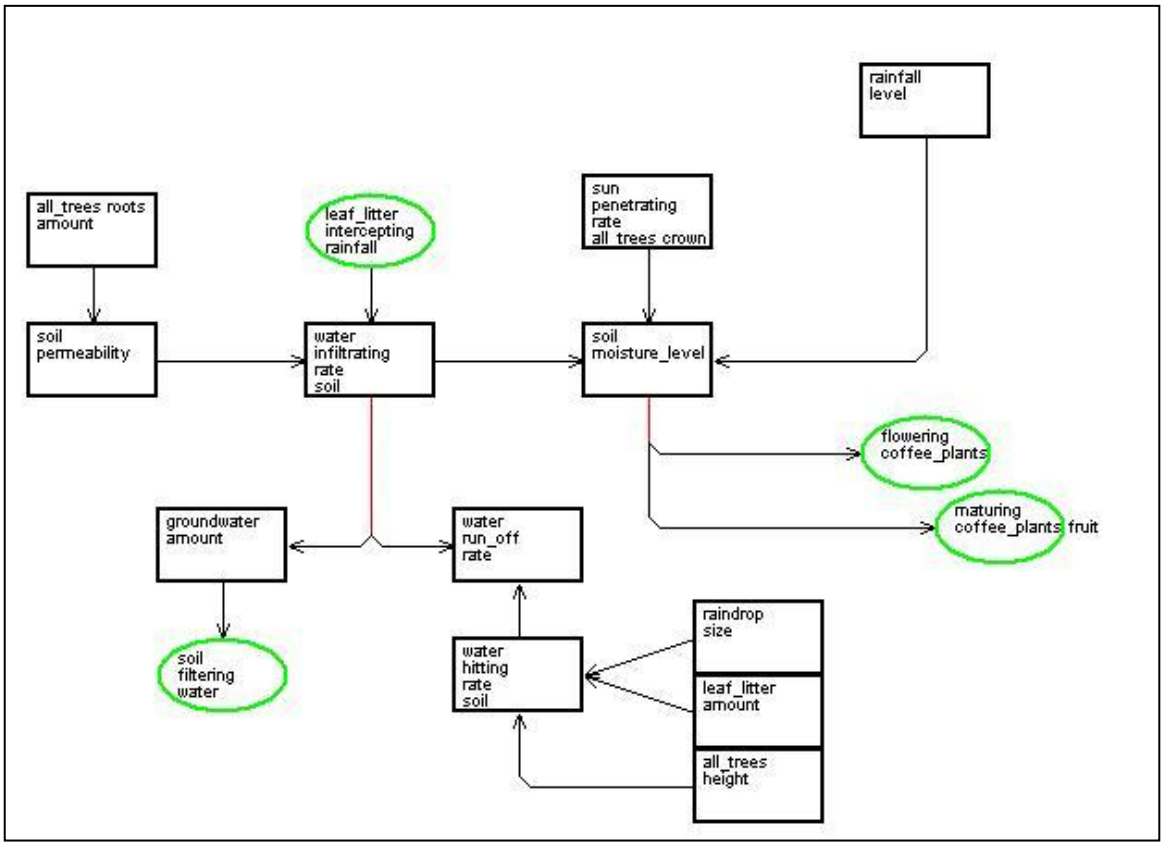

Figure 17. Causal diagram representing farmers' knowledge of trees, water and impacts on coffee. Nodes represent natural processes (ovals) or attributes of objects, processes or actions (boxes with straight edges). Arrows connecting nodes denote the direction of causal influence.

4.4.1 Discussion of Table 6

Many of the trees that were classified as 'fresh' were thought to be good for water, whereas, 'caliente' trees (translated as 'hot trees') were strongly related to low protection of water. However, as indicated in Table 6, such attributes could not be applied to *all* caliente trees or *all* fresh trees.

For instance, cordoncillo (*Piper adumcum*) was classed as a 'caliente tree' but some farmers perceived it as a 'good' tree for protecting water sources, mainly because the natural growth of the species was observed to be in humid places. Furthermore, yaje (*Acacia acanthophylla*) was a 'fresh tree' but was only considered a 'fine' tree for protecting water sources; and, caulote (*Guazuma ulmifolia*), which does not fit into either of the 'fresh' or 'caliente' classifications, was also considered a 'fine' tree for protecting water sources. In the case of the trees that were not seen to be protecting water, peach (*Prunus persica*) and cola de pavo (*Cuprania glabra*) were both considered in this way, the latter being a 'caliente tree' and the former being a species that did not fit into either 'caliente' or 'fresh' categories.

Table 6. A sample of tree attributes in relation to water provisioning services[6]. 'Good' means that the tree was said to decrease soil erosion, maintain soil moisture and protect water sources. The opposite is true for 'bad'. Trees with 'fine' value meant that the impact was classed as negative but either because of their abundance, or for another tree attribute, their impact was not so bad overall.

Tree species	Fresh or Caliente	Impact on soil erosion	Impact on soil moisture	Impact on water sources
Piper adumcum	-	-	Good	Good
Inga oerstediana	Fresh	Good	Good	Good
Inga vera	Fresh	Good	Good	Good
Inga laurina	Fresh	Good	Good	Good
Inga edulis	Fresh	Good	Good	Good
Inga jinicuil	Fresh	Good	Good	Good
Quercus peduncularis	-	-	Good	Good
Quercus sapotifolia	-	-	Good	Good
Liquidambar styraciflua	-	Good	Good	Good
Syzygium spp.	-	Fine	Good	Good
Pinus maximinoi	-	Good	Good	Good
Pinus oocarpa	-	Good	Good	Good
Manilkora zapota	-	Fine	Good	Good
Acacia acanthophylla	Fresh	Good	Good	Fine
Guazuma ulmifolia	-	-	Good	Fine
Citrus sinensis	-	Fine	Fine	Bad
Citrus reticulata	-	Fine	Fine	Bad
Yucca elephantipes	-	Good	Bad	Bad
Vernonia patens	Caliente	Fine	Fine	Bad
Zanthoxylum caribaum	-	Bad	Fine	Bad
Perymenium grande	Caliente	Fine	Bad	Bad
Prunus persica	-	Bad	Bad	Bad
Ricinus communis	-	Bad	Bad	Bad
Colubrina guatemalensis	Caliente	Bad	Bad	Bad
Cupania glabra	Caliente	Bad	Bad	Bad

[6] See Appendix 4 for a full table that shows all the trees that farmers mentioned in relation to soil and water.

4.4.2 Summary

Farmers showed a good understanding of which trees were useful in terms of decreasing soil erosion and maintaining soil moisture and deeper groundwater. But, the reasons for keeping particular trees on coffee plantations was not always for these purposes; a tree would often have to prove itself useful in additional ways to be kept there, for example providing a food source. Where there was an important water source, however, farmers were more careful and did not tend to disturb the natural species composition around these areas incase it led to a diminishing water supply. Within coffee plantations, it was not just the tree species that was important for maintaining soil moisture, pruning at different levels for different times of the year according to where the farm was situated was also important.

Tools

Useful AKT5 tools:

- Comparative analysis tool 'topic_hierarchy_assignment' (found in AKT5/Tools/System Tools/Comparative Analysis). Shows the number of statements attached to each topic hierarchy in the knowledge base.
- Cafnet tool 'interactions_amongst_components'. The user can select which object hierarchies and/or singular objects from a formal term list to include in the tool output (e.g. for column selection, select 'all trees' plus subobjects, then for row selection, select 'soil', 'water', 'rainfall', and 'rainy season'). Shows how many times objects appear in the same statements.

4.5 Coffee productivity and its relationship with agroforestry practices

Trade-offs among ecosystem services and coffee productivity was well understood by farmers. This understanding was strongly linked with the abundance of trees within coffee plantations (Table 7). Not all the goods and services that farmers could obtain from trees were valued in the same way (as referred to in 4.1), for instance timber was perceived as more useful than trees attracting pollinator species. The abundance of particular tree species could be seen to rely on decisions made by farmers, decisions that were influenced by the services a tree could provide and whether those aspects outweighed any negative impacts on coffee plants, or, alternatively, whether a trees positive impact on coffee outweighed the need for additional services from it. It was generally regarded as better for farmers to have species that provided few services but did not impact negatively on the coffee plants. Usually, if farms were big enough, there were separate areas designated for timber trees (forests) and coffee plants, to avoid competition that would adversely impact upon coffee productivity.

4.5.1 Discussion of Table 7

The main damage that trees were seen as causing to coffee plants were related to soil aspects: competition for nutrients or water, decrements in soil quality (fertility, structure, moisture). Sun light availability was also mentioned, especially with trees that had large dense crowns. Positive impacts were mainly related with organic matter deposition, which was improving the soil condition for coffee plants.

Some trees that had negative effects on coffee plants could also be found within plantations. The presence of these trees was explained either due to necessary goods they were providing the farmer or just because elimination of them could be complicated (felling trees could cause more damage than keeping them in the landscape). Trees with negative effects on coffee were at the same time providing important resources for farmers. The most common trade off between coffee productivity and other ecosystem service provision was occurring when farmers kept trees within the plantation as a source of timber or firewood. The case of *Perymenium grande* is a good example of this. Even though farmers recognised that it was highly competitive with coffee plants, it was still present in a low abundance on many farms, just because the wood from it was commonly used for making fences.

Even though trade-offs between coffee productivity and ecosystem services were clearly understood by farmers, they also mentioned trade-offs between ecosystem services, especially between provisioning and regulating services. An example of this was that many of the trees protecting water sources were not used to obtain timber, either because they did not have quality timber and/or because they were observed to be providing a more important service of protecting valuable water sources. Amate (*Ficus glabrata*), capulín (*Trema micrantha*) and cordoncillo (*Piper adumcum*) were species that were all considered able to protect water sources, while their firewood or timber was deemed not useful. Another example of a trade-off between provisioning and regulating services could be seen between soil erosion control and fruits provision; amate (*Ficus glabrata*), ciprés (*Cupressus lusitanica*), cuje (*Inga vera*), gravilea (*Grevillea robusta*), guachipelin (*Dyphisa americana*), bálsamo (*Liquidambar styraciflua*), pino blanco (*Pinus maximinoi*), pino colorado (*Pinus oocarpa*) and yaje (*Acacia acanthophylla*) all had roots that were said to combat soil erosion, but not one of them was providing edible fruits for farmers' diets.

Table 7. A sample of trees, their varying impacts on coffee productivity and the main reasons given by farmers for keeping them on farms.

	Tree species	**Impact on coffee**	**Reasons to keep in farm**
With high abundance	*Inga* spp.	(+) Provide organic matter (+) Protect coffee against sun, rainfall and frosts (+)Soil maintenance	Shade coffee, firewood, easy to prune and manage
	Musa spp.	(+) Provide organic matter (+) Soil maintenance	Shade coffee, fruits
	Yucca elephantipes	(+) Soil maintenance (-) Decrease soil moisture (-) Decrease soil fertility	Fence, edible flower, avoid erosion
	Eryobotria japonica	(+) Soil maintenance	Shade coffee, fruits
	Chamaedorea spp.	(+) Soil maintenance	Sprouting eatable
	Sabal mexicana	(+) Soil maintenance (+) Keep soil moisture (+) Provide organic matter	Edible, leaves used for building
	Acacia acanthophylla	(+) Soil maintenance (+) Keep soil moisture (+) Provide organic matter	Shade coffee
	Persea americana	(+) Soil maintenance (+) Keep soil moisture (+) Provide organic matter (-) More foliage than coffee requires	Shade coffee, fruits, medicinal
	Persea schiedeana	(+) Soil maintenance (+) Keep soil moisture (+) Provide organic matter (-) More foliage than coffee requires	Shade coffee, fruits
With medium abundance	*Grevillea robusta*	(+) Soil maintenance (+) Keep soil moisture (+) Provide organic matter	Shade coffee, regular firewood
	Trema micrantha	(-) More soil moisture than coffee requires	Birds eat fruits
	Guazuma ulmifolia	(+) Provide organic matter (-) More foliage than coffee requires	Regular firewood, medicinal
	Cedrela odorata	New species used within the area, people has not experience	Timber
	Cedrela tonduzii		
	Liquidambar styraciflua	(+) Soil maintenance (-) Competitive effect with coffee	Regular firewood, regular timber, medicinal
	Erythrina berteroana	(+) Soil maintenance (+) Keep soil moisture (+) Provide organic matter	Shade coffee, edible flower
	Manilkora zapota	(+) Keep soil moisture	Fruits, timber, firewood
With low abundance	*Perymenium grande*	(-) Competitive effect with coffee	Fences
	Casimiroa edulis	(+) Keep soil moisture (-) More foliage than coffee requires	Fruits
	Lantana camara	(+) Keep soil moisture	Regular firewood
	Colubrina guatemalensis	(-) Competitive effect with coffee	Regular timber (just branches)
	Piper adumcum	(-) Competitive effect with coffee	Nothing
	Diphysa americana	(+) Soil maintenance (+) Keep soil moisture (+) Provide organic matter	Good timber (but few), also it is difficult to manage

4.5.2 Coffee agroforestry in comparison to other land uses

Farmers and the wider population from the research communities considered forest as the land use which provided the most ecosystem services, especially if they were located in the higher areas and near to the rivers. The 'services' that people could easily perceive were biodiversity conservation, water provision, maintenance of soil and weather regulation. Natural forest was considered the ideal land use in terms of environment and maintaining a healthy ecosystem, while coffee agroforestry plantations were second ranked, particularly if they were intercropped with a considerable amount of shade trees. Farmers stated that not all coffee plantations were providing the same amount of ecosystem services; the main differences being the amount of trees, location and size of farms. Last in rank, for ecosystem service provision, were beans, maize and tomatoes plantations. This was primarily due to the fact these crops were not intercropped as they had low tolerance for shade.

Even when coffee was the main cash crop, maize and beans were frequently grown on separate plots for self consumption. During the research period, tomato plantations were increasingly being established and people could compare the effect of these plantations with coffee in relation to ecosystem services. Farmers mentioned that crop plantation establishment led to a double problem: first, because forestry areas were cleared to establish them, and, secondly, because these crops were not providing ecosystem services other than for farmers' livelihoods. Plantations were said to often cause erosion and degradation of soil, as well as having high water requirements in areas where little was available and/or causing pollution (especially with tomato growing which requires many chemical inputs). With a basic understanding that less trees leads to less 'services' people tried to explain the local situation (Plate 6).

Plate 6. Left side: newly established coffee plantation bordering the forest. Right side: tomatoes growing without tree cover. Photographs taken by Rudy del Cid, August 2008.

4.5.3 Summary

Because coffee was the main source of income in the research communities, farmers were carrying out management practices and taking decisions on a productivity basis, with the ultimate aim of increasing quality and yield of coffee. Decisions were also taken after considering labour requirements in relation to the net benefit obtained from an increase in coffee yield. Although some of these decisions were not heavily affecting the provision of ecosystem services, as it could be simply selecting one coffee variety over another, there were many decisions and resultant practices that had the ability to greatly enhance or decrease coffee plantations ability to provide ecosystem services.

Shade canopy composition selection and management were the main factors through which farmers were able to influence coffee plantations' impacts on the environment, and farmers generally considered that the impact of ecosystem services was directly linked with the size of coffee farm (larger farms tended to be more intensive with less shade trees intercropped with coffee). The 'services' a coffee plantation was able to provide depended on decisions revolving around the amount of trees, the diversity of trees and, also, the time and way in which trees would be kept within the farm, as a temporal tree, permanent tree or a tree with high level pruning.

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Appendix 1: Tools for analysing the knowledge

The '**Tools**' in AKT5 perform automated reasoning. '**System tools**' come with the AKT5 software, whereas, '**Other User Tools**' are developed with a specific knowledge base or collection of knowledge bases in mind (in this case CAFNET knowledge bases). The tools enable the user to analyse and compare knowledge in a much more powerful manner than would otherwise be possible using simple '**Boolean search**' operations.

Tools are used primarily for two distinct functions - 1) to facilitate the development of knowledge bases and 2) knowledge base exploration (especially when there is more than one knowledge base to be interrogated at the same time).

Table 8. Useful tools for CAFNET knowledge bases.

Name of Tool	Description	Tool Location
knowledge_base_report	Produces a report that summarises the main Kb content	System tools/ Knowledge Evaluation
formal_terms_table	Tabulated output that shows all formal terms and their presence across all open Kbs	System tools/ Comparative Analysis
interactions_amongst_components	Tabulated output that shows the number of interactions between object hierarchies or singular objects within the Kb statements	Other User Tools/ cafnet_tool file
phenology analysis	Comparative analysis tool that pulls up all common topics across Kbs and presents the topic search terms (e.g. flowering, pollinating) with their associated objects, attributes and values in a tabulated output	Other User Tools/ cafnet_tool file
get_components(Kb,Objects,Synonyms)	Pulls up all selected objects and their	Other User Tools/ cafnet_tool file

	synonyms	
get_objects(Kb,Objects)	Pulls up all selected objects with their subobjects and/or superobjects depending on user specified search criteria	Other User Tools/ cafnet_tool file
hierarchic_objects_usage	Compares objects across object hierarchies and shows which hierarchies they appear in	Other User Tools/ cafnet_tool file
hierarchical_actions_and_processes	Shows the actions and processes associated with the objects within a selected object hierarchy	Other User Tools/ cafnet_tool file

Appendix 2: Glossary

Table 9. Key terminology and concepts using AKT5.

AKT5 term	Description
Action	A type of formal term used to refer to a human activity, usually for the purpose of managing crops or livestock, e.g. 'weeding' or 'planting'
AKT5	Agroecological Knowledge Toolkit: a methodology and software for creating knowledge bases
Attribute	A type of formal term used to describe an object, process or action. Attributes are generally measurable e.g. height, colour, frequency, rate, gradient, temperature
Boolean Search	A keyword search mechanism for retrieving statements containing particular key words. Any combination of words may be used in conjunction with 'AND' and 'OR'
Causal statement	A statement about the causal relationships between two objects, processes or actions
Comparison	A type of formal term used in comparison statements
Comparison statement	A type of statement that compares the properties of two objects
Conditions	The conditions that need to be in place for a specific statement to be true
Control structures	When working with tools: program segments within AKT5 which control when and upon what knowledge primitives are used
Data	A set of observations which may be quantitative or qualitative
Derivation	The origin of the information given by a source (e.g. observed, hearsay, unknown)
Diagram	A way of graphically representing causal and link statements
Formal language	The restricted syntax (grammar) by which knowledge is entered into AKT5
Formal term	Terms (words) that constitue a formal language statement that do not belong to the reserved AKT5 grammar
Knowledge	The outcome, independent of the interpreter, of the interpretation of data or information
Knowledge base (Kb)	An articulated and defined set of knowledge stored on a computer which can be accessed and processed systematically
Link	a) A type of formal term used in a link statement b) On a diagram – the connection between two nodes represented by an arrow
Link statement	A type of statement used to represent knowledge

	that cannot be represented by any other type of statement
Local knowledge	Knowledge based on a locally derived understanding, formed by experience and observation
Memo	A facility within AKT5 which provides the Kb creator with space to add any additional explanatory information about a knowledge base, formal term, statement, bit map, diagram, topic.
Natural language statement	A statement which has been automatically translated by AKT5 from the 'formal language' to a 'natural language' computer stylised translation
Navigate	A command used when working with diagrams that adds to a diagram all the causal nodes immediately associated with a user selected node
Node	Causal and link statements can be represented on a diagram by two nodes connected by a link. A 'node' is the diagrammatic representation of one half of a causal or link statement and appears as a rectangular or circular box. There are four types of node: i) objects, ii) processes, iii) actions and iv) attributes of either objects, processes or actions
Object	A type of formal term used to refer to a material or conceptual thing e.g. pests, shade trees or coffee plantation
Object hierarchy	A way of organising knowledge about specific objects under more generic terms e.g.*avocado trees* and *bananas* are all types of fruit tree
Primitives	Small program segments within AKT5 employed for running a tool
Process	A type of formal term used to refer to a change or a flux in the natural world e.g. decomposition, erosion
Prolog (WinProlog)	An artificial intelligence programming language used for developing AKT5 software
Source	The origin of the information contained within a statement. There are two types of sources: interview sources and reference sources
Subobject (of an object)	An object that appears below another object in an object hierarchy e.g. '*Grevillea robusta*' would be a subobject of 'trees'
Superobject (of an object)	An object that appears above another object in an object hierarchy. e.g., 'trees' would be a superobject of '*Grevillea robusta*'
Synonym	A word with the same meaning as a formal

	term; usually used to denote a local or scientific name for a specified species, and as a method for switching between English and the language of the particular research site. There can be any number of synonyms.
System tools	Tools stored within AKT5 which can be used to interrogate and evaluate the content within knowledge base(s)
Tool	A small computer program supplied with AKT5 that serves to interrogate and reason with the content of the knowledge base(s)
Topic	A collection of statements organised around a particular topic e.g. 'bio-indicators of clean water' or 'miang pests'
Topic hierarchy	A collection of topics organised under a broader 'umbrella' topic area
User defined tools	Tools created by the knowledge base user that are stored separately to the main AKT5 program file with an .mcr extension
Value	A type of formal term that is always attached to an attribute and describes that attribute e.g. 5kg, yellow, high, increase
WinAKT	The old name for AKT5: Agroforestry Knowledge Toolkit for Windows

Appendix 3: Full ecosystem services table showing the information available for all the tree species that are represented in the cafnet_guatemala knowledge base.

Table 10. Ecosystem services table showing the information available for all the tree species that are represented in the cafnet_guatemala knowledge base.

Presence within farm	Tree species	Providing services				Regulating services					
		Soil formation	Food source	Firewood/ timber	Medicinal	Water regulation	Climate regulation	Soil stability (erosion)	Disease and pest regulation	Pollination	Resources for biodiversity
Common species	*Coffea arabica**	0	+	+	0	0	0	+	-	+	+
	Inga vera	+	0	+	0	+	+	+	0	+	+
	Banana - Undefined	+	+	0	0	+	+	+	0	+	+
	Guineo - Undefined	+	+	0	0	+	+	+	0	+	+
	Chamaedora tepejilote	0	+	0	0	0	0	+	0	0	+
	Eryobotria japonica	0	+	0	0	0	+	+	0	+	+
	Psidium guajava	+	+	+	+	0	0	0	0	0	+
	Citrus sinensis	0	+	0	+	0	0	0	0	+	+
	Persea americana	+	+	0	+	0	+	+	0	+	+
	Persea schiedeana	+	+	0	0	0	+	0	0	0	+
	Trichilia americana	0	0	+	0	+	0	0	0	0	0
	Cupressus lusitanica	0	0	+	0	+	+	+	0	0	0

Cupania glabra	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Piper adumcum	**0**	**0**	**0**	**0**	+	**0**	**0**	**0**	**0**	+
Prunus persica	**0**	+	**0**	**0**	**0**	**0**	**0**	**0**	+	+
Quercus peduncularis	**0**	**0**	+	+	+	**0**	**0**	**0**	**0**	+
Quercus sapotifolia	**0**	**0**	+	+	+	**0**	**0**	**0**	+	+
Inga jinicuil	+	+	+	**0**	+	+	+	**0**	+	+
Inga edulis	+	+	+	**0**	+	+	+	**0**	+	+
Cecropia obstusifolia	**0**	**0**	**0**	+	**0**	**0**	**0**	**0**	**0**	+
Ricimus communis	+	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Yucca elephantipes	**0**	+	**0**	+	**0**	**0**	+	**0**	**0**	**0**
CItrus aurantifolia	-	+	**0**	+	**0**	**0**	**0**	**0**	**0**	**0**
Citrus limonia	-	+	**0**	+	**0**	**0**	**0**	**0**	**0**	**0**
Liquidambar styraciflua	**0**	**0**	+	+	+	**0**	+	**0**	**0**	+
Sabal mexicana	+	+	+	**0**	**0**	**0**	+	**0**	**0**	+
Pinus maximinoi	**0**	**0**	+	+	+	**0**	+	**0**	**0**	+
Gliricidia sepium	+	+	+	**0**	**0**	+	+	**0**	**0**	**0**
Pinus oocarpa	**0**	**0**	+	+	+	**0**	+	**0**	**0**	+
Perymenium grande	-	**0**	+	**0**	**0**	**0**	**0**	**0**	**0**	+

	Acacia acanthophylla	+	0	0	0	+	+	+	+	0	0
Less common species	*Inga* oerstediana	+	**0**	+	**0**	+	+	+	**0**	+	+
	Inga laurina	+	+	+	**0**	+	+	+	**0**	+	+
	Banano habanero amarillo	+	+	**0**	**0**	**0**	+	+	**0**	+	+
	Banano habanero morado	+	+	**0**	**0**	**0**	+	+	**0**	+	+
	Banano majunche	+	+	**0**	**0**	**0**	+	+	**0**	+	+
	Banano manzanito	+	+	**0**	**0**	**0**	+	+	**0**	+	+
	Ficus glabrata	**0**	**0**	**0**	+	+	**0**	+	-	**0**	+
	Muntingia calabura	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	+
	Guazuma ulmifolia	+	+	+	+	+	**0**	**0**	**0**	**0**	**0**
	Ceiba aesculifolia	**0**	**0**	+	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Lonchocarpus minimiflorus	**0**	**0**	+	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Trema micrantha	**0**	+	**0**	**0**	+	**0**	**0**	**0**	+	+
	Cedrela odirata	**0**	**0**	+	**0**	+	**0**	**0**	**0**	**0**	**0**
	Cedrela tonduzii	**0**	**0**	+	**0**	+	**0**	**0**	**0**	**0**	**0**

	Saurauia laevigata	**0**	+	+	**0**	+	**0**	**0**	**0**	**0**	+
	Lantana camara	**0**	**0**	+	**0**	**0**	**0**	**0**	**0**	**0**	+
	Colubrina guatemalensis	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Grevillea robusta	+	**0**	+	**0**	**0**	**0**	+	**0**	**0**	**0**
	Diphysa americana	+	**0**	+	**0**	**0**	**0**	+	**0**	**0**	**0**
	Spondias monbin	**0**	+	**0**	**0**	**0**	**0**	**0**	**0**	**0**	+
	Citrus paradisi	**0**	+	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Mangifera indica	**0**	+	**0**	+	**0**	**0**	**0**	**0**	**0**	+
	Citrus reticulata	**0**	+	**0**	**0**	**0**	**0**	+	**0**	**0**	+
	Dendropanax arboreus	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Syzygium jambos	**0**	+	**0**	+	+	-	+	**0**	**0**	+
	Casimiroa edulis	+	+	**0**	**0**	**0**	**0**	+	**0**	**0**	+
	Mielero - Undefinied	**0**	+	**0**	**0**	**0**	**0**	**0**	**0**	**0**	+
	Zanthoxylum caribaum	**0**	+	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Erythrina berteroana	+	+	**0**	**0**	**0**	+	+	+	**0**	**0**
	Vernonia patens	+	**0**	**0**	+	**0**	**0**	+	**0**	**0**	**0**

	Manilkora zapota	+	+	+	+	+	**0**	+	**0**	**0**	+
	Swietenia humilis	**0**	**0**	**0**	**0**	+	**0**	**0**	**0**	**0**	**0**
	Solanum bansii	+	**0**	**0**	**0**	**0**	+	**0**	-	**0**	+

Key: (**0**) indicates a neutral effect on the service indicated, (+) indicates a positive effect on the service indicated, (-) indicates a negative effect on the service indicated.
* The role and classification of coffee according to farmers was not as a tree, it was placed in this table just to show how it compares with the shade trees it is intercropped with in terms of ecosystem service provision.
† Many species of Inga have edible fruits, but they were not considered a food source because the fruits were not part of the farmers' diets

Appendix 4: Trees and their impacts on soil and water

Table 11. Full list of the trees present in the cafnet_guatemala knowledge base that farmers gave information about with regards to impacts on soil and water.

Tree species	Fresh or caliente	Impact on soil erosion	Impact on soil moisture	Impact on water sources
Ficus glabrata	Fresh	Good	Good	Good
Trichilia americana	Caliente	Bad	Good	Good
Trema micrantha	Fresh	Bad	Good	Good
Saurauia laevigata		Bad	Good	Good
Cupressus lusitanica	Caliente	Good	Good	Good
Piper adumcum	Caliente	Bad	Bad	Good
Inga oerstediana	Fresh	Good	Good	Good
Inga vera	Fresh	Good	Good	Good
Inga laurina	Fresh	Good	Good	Good
Inga edulis	Fresh	Good	Good	Good
Inga jinicuil	Fresh	Good	Good	Good
Quercus peduncularis	Caliente	Bad	Good	Good
Quercus sapotifolia	Caliente	Bad	Good	Good
Liquidambar styraciflua	Caliente	Good	Good	Good
Syzygium jambos		Fine	Good	Good
Pinus maximinoi	Caliente	Good	Good	Good
Pinus oocarpa	Caliente	Good	Good	Good
Manilkora zapota		Fine	Good	Good
Swietenia humilis		Bad	Good	Good
Acacia acanthophylla	Fresh	Good	Good	Fine
Guazuma ulmifolia		No	Good	Fine
*Bixa orellana**		Good	Fine	Bad

Persea americana		Good	Good	Bad
Persea schiedeana		Fine	Good	Bad
Banana - Undefinied	Fresh	Good	Good	Bad
Guineo - Undefinied	Fresh	Good	Good	Bad
Banana majunche	Fresh	Good	Good	Bad
Banano manzanito	Fresh	Good	Good	Bad
Banano habanero amarillo	Fresh	Good	Good	Bad
Banano habanero morado	Fresh	Good	Good	Bad
*Elettaria cardamomum**	Fresh	Good	Fine	Bad
Solanum bansii	Fresh	Bad	Good	Bad
Grevillea robusta	Fresh	Good	Good	Bad
Diphysa americana	Fresh	Good	Good	Bad
Gliricidia sepium	Fresh	Good	Good	Bad
Chamaedora tepejilote	Fresh	Good	Good	Bad
Erythrina berteroana	Fresh	Good	Good	Bad
Muntingia calabura		Bad	Good	Bad
Cedrela odorata		Bad	Good	Bad
Cedrela tonduzii		Bad	Good	Bad
Ceiba aesculifolia		Bad	Good	Bad
Lonchocarpus minimiflorus		Bad	Good	Bad
Lantana camara		Bad	Good	Bad
Citrus sinensis		Fine	Fine	Bad
Citrus reticulata		Fine	Fine	Bad
Yucca elephantipes		Good	Bad	Bad
Vernonia patens	Caliente	Fine	Fine	Bad

Zanthoxylum caribaum		Bad	Fine	Bad
Perymenium grande	Caliente	Fine	Bad	Bad
Prunus persica		Bad	Bad	Bad
Cecropia obstusifolia		Bad	Good	Bad
Psidium guajava		Bad	Good	Bad
Ricinus communis		Bad	Bad	Bad
Spondias monbin		Bad	Good	Bad
Citrus aurantifolia		Bad	Good	Bad
Citrus paradisi		Bad	Good	Bad
Citrus limonia		Bad	Good	Bad
Mangifera indica		Bad	Good	Bad
Casimiroa edulis		Fine	Good	Bad
Mielero - Undefined		Bad	Good	Bad
Eriobotrya japonica		Good	Fine	Bad
Sabal mexicana		Good	Good	Bad
Dendropanax arboreus	Caliente	Bad	Bad	Bad
Spathodea campanulata	Caliente	Fine	Bad	Bad
Colubrina guatemalensis	Caliente	Bad	Bad	Bad
Cupania glabra	Caliente	Bad	Bad	Bad

*Achiote (*Bixa orellana*) and cardamom (*Elettaria cardamomum*) were shrubs intercropped with coffee and were not classified as trees, but they were also mentioned by farmers in relation to soil and water.

Key: 'Good' means that the tree was said to decrease soil erosion, maintain soil moisture and protect water sources. The opposite is true for 'bad'. Trees with 'fine' value meant that the impact was classed as negative but either because of their abundance, or for another tree attribute, their impact was not so bad overall.